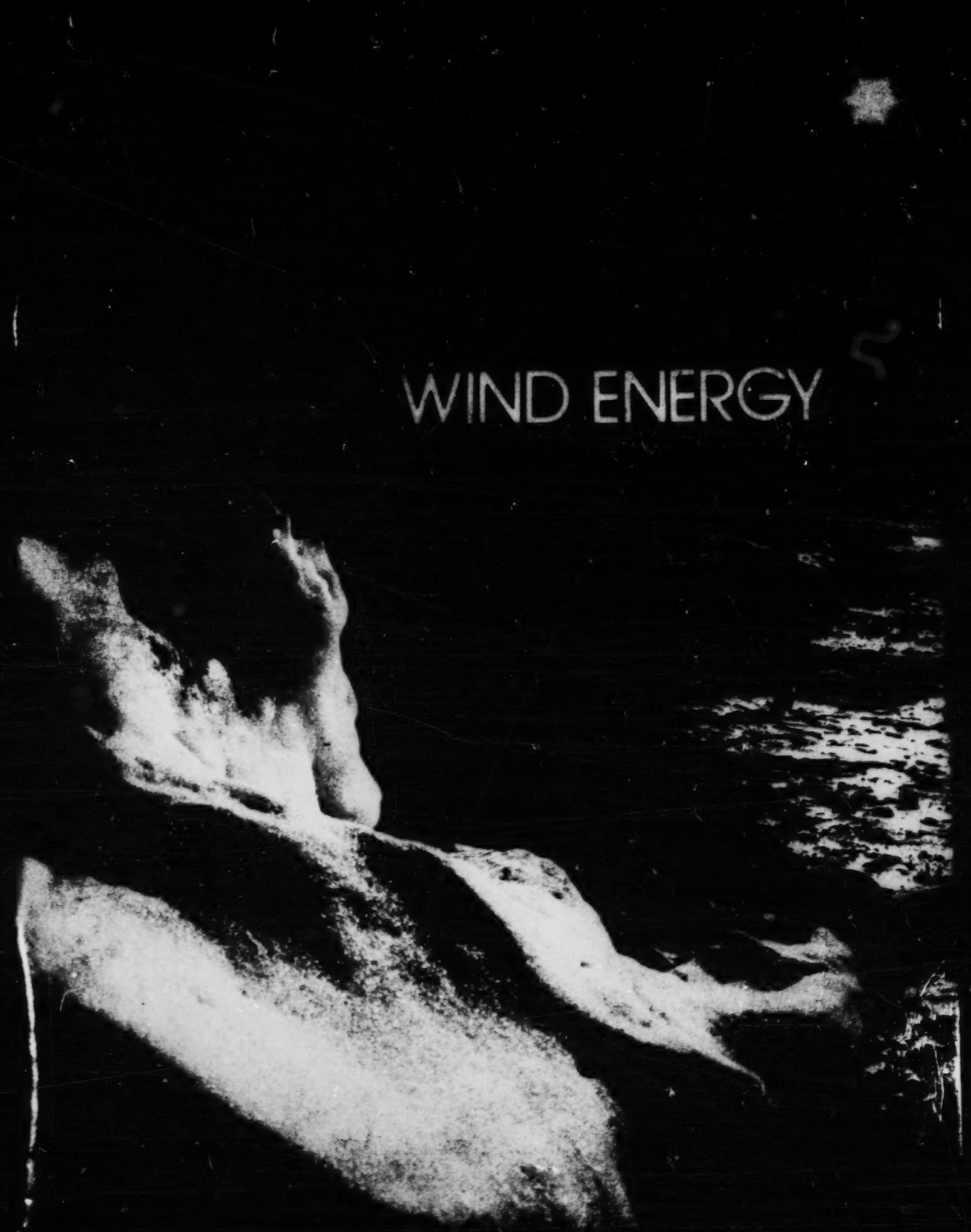
WIND ENERGY



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Northwest Territories Science Advisory Board
Alberta Research Council

WIND ENERGY
in the Northwest Territories

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prepared for
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THE NORTHWEST TERRITORIES
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Wind Energy
in the Northwest Territories

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Foreword

Faced with rapidly escalating energy costs, government agencies and public utilities are actively searching for ways out of one of our northern dilemmas — an unusual degree of dependence upon oil both for heating and for electricity. A number of energy alternatives appear to hold interesting possibilities. However, making comparisons between the possible alternatives is difficult, since little detailed information is available.

This report represents an attempt to provide a more detailed analysis of one alternative, wind. It is the result of a cooperative venture on the part of three agencies, each having an interest in wind energy in the North. The Atmospheric Environment Service of Environment Canada provided the data. Staff members of the Arctic Weather Centre undertook the preparation of the major portion of the manuscript and provided magnetic tapes of weather data. The Solar and Wind Energy Research Program of the Alberta Research Council provided the analyses of the data and generated the site-specific graphs and charts. The Science Advisory Board initially identified the need for such a study and looked after the major part of the funding and the printing.

The specific objectives of this report are:

1. To present the wind-energy climatology of the Northwest Territories.
2. To define geographical areas of the Northwest Territories in terms of the feasibility of converting wind energy to usable domestic or industrial energy.
3. To generate site-specific design data for selected stations in the Northwest Territories.
4. To alert the reader to the vagaries of the wind climate of the Northwest Territories.
5. To provide sufficient theoretical background to enable the reader to appreciate the findings of this report without exhaustive reference to other literature.

The Science Advisory Board feels that this report should provide a basis to enable governments and utilities to make intelligent decisions regarding wind-energy applications in the Northwest Territories. The data may also provide answers for those considering domestic ventures into the field of wind energy.

R. K. Bell,
Executive Secretary.

Executive Summary

The wind has blown across the Arctic for hundreds of years. Men have cursed it and some have even died because of it. Anyone who has survived a northern blizzard knows that the wind has a great deal of energy. A few people have harnessed this energy for their own use but up until now this form of energy has not been used on a large scale in the Northwest Territories. With our present high energy costs it is a good time to look at using wind energy in the Northwest Territories. This report looks at historical wind data and presents information as graphs and maps.

Two separate methods were used to prepare this information. In the first, historical wind data from over fifty stations were put together to form an annual wind-energy map. The map was then used to show four different areas of wind energy.

The second method involved a more complicated computer study of the data. This study produced the graphs and tables in the report.

Results of the study show that for those interested in harnessing the wind in the Northwest Territories there is both good news and bad news. For the good news, large parts of the Northwest Territories, for example, the Keewatin, have winds as good or better than any other sites in North America. The bad news is that the study shows that large areas of the western Northwest Territories can get little benefit from this resource. This information is shown on a wind-energy map of the Northwest Territories. That map shows the parts of the Northwest Territories that have poor, fair, and good wind energy zones.

Any attempts to harness wind energy in the Northwest Territories will have to deal with a number of problems. These include getting the bulky and complicated equipment to the site, equipment breaking because of the cold, and the need for special greases and oils that work well in the cold.

It is hoped that this information will be of use to government agencies and power companies such as NCPC. Maybe the homeowner can get some ideas as well, if he is interested in small wind-energy applications.

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Ayongnaiyakhimayok Atangoyan Titigakhimayan

Kinalikak inohimayok pikhiktomi ilihimayok anogi hakogiktok. Ikitton Inuit atokpagan hamna anokim aolania kihimi ona atoktaohimaitok angiyomik nunatiami. Akittokpalakmata taya algoyaktotivot nakohiyok ihomagiyami atongnik anogim hakogiotanik nunatiami. Una titigakhimayok ihivgioktan atongnik anogimik taimani naonaitkotaniklo titigakhimayonik.

Malgok hanayotik atuni ittok atoktaohimayok hamna naoaniyaknik havakhogo. Hivolikmi, katitiktaovakton anogimik atoknit taimani 50 nit ihivgiokvingnit piplotik okiok taman anokim hakotainik titgaoyanik. Titigakhimayom naonaikpagain hitaman allatkin homi anokim aolanin.

Aipa hanatyot ayongnavyaktok ilakagami kagitangoanik ihivgioktonik katitikhimayonik naonaitkotanik. Una ilitokhoinik pivaktok naonaitkotinik titigakhimayomi.

Inigotain ilitokhoiyotim naonaiktitpagain tapkoa Inuit oktogomayon atoglogin anokim hakogiyotain nunatiami tohaktakhain nakoyoklo nakongitoklo. Ona nakoyok tohaktakhan angiyon ilain nunatiam omaton kivallimiut, anokhiyokton nakotkianik nunanit hamanga. Nakongitok taok tohaktakhak ilitokhoiyotim naonaiktitpagain angiyok nuna uslinikmi imaiiolimaitok. Hamna naonaiyaot pihimayok talvani anogim aolania titigaoyakhimayomi nunatiami. Una naonaikpagain nunan nakongiton, nakovyakton, nakoyolo anogiknit homi.

Kitolikak pinahoangnik anogim aolanianik nunatiami ayokhaotin pangniaktaoyon. Hapkoa ilagiyain akyangnik tamayanik ihivgiokvikhanot ahigoktingnik hanalgotinik kikitkangamik ihagiaginiklo okhoktigotinik nakoyonik kikitmi.

Hamna naonaiyaktaohimayok atoktitomayan kavamatkot havakvini tapkaolo algoyaktoktitiyin ilakakton N.C.P.C. konik. Iglokaktolo hona allanik ihomakakton anogim aolatyotikhainik atogomagomik.

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R. K. Bell: Science Advisory Board, became involved in the project when it was sagging a little. His gentle prodding and encouragement ensured its completion. He looked after the printing and publishing.

Biographical Notes on Authors

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Gordon Howell is an electrical engineer with the Solar and Wind-Energy Research Program of the Alberta Research Council. He is responsible for the development of computer software for processing solar and wind data from the SWERP monitoring network and for meteorological data from other sources such as the Atmospheric Environment Service. Mr. Howell has worked on a number of other research projects including the software development for the simulation of ice build-up on monopod drilling structures in the Beaufort Sea. He is an active member of the Solar Energy Society of Canada and is a lecturer on solar-energy applications. He has published several papers dealing with wind and solar energy in Canada.

Andrew Serna is a supervisor in the Arctic Weather Centre of the Atmospheric Environment Service. His responsibilities include the ensuring of a high quality forecast service for the Northwest Territories. He has been forecasting for the Canadian Arctic for the last nine years and prior to coming to the Arctic Weather Centre had a wide range of meteorological experience having served in Goose Bay, Gander, and Portage la Prairie, Manitoba. He served overseas with the Canadian Armed Forces in Germany for a three-year period in the early 1970's. Mr. Serna has made a number of trips into the far north on behalf of the Atmospheric Environment Service and has prepared internal reports on these trips.

1. Introduction

1.1 BACKGROUND

Within the past decade the energy-consuming lifestyle of the western world has received a rude shock — the era of cheap energy has come to an end. Oil embargoes, rising utility costs, fuel shortages, and ominous hints of gasoline rationing have forcibly and dramatically alerted us to our dependence on energy in its various forms. The residents of the Northwest Territories, like their southern cousins, are fully aware of their dependence on energy — not only to maintain their lifestyles, but to survive.

The use of energy intrudes itself on all facets of northern life, the main energy source being fossil fuels. The harsh climate and the high latitudes allow fewer alternative energy sources than in southern Canada. Hydro power has possibilities in some areas, but poses obvious difficulties in winter. Biofuels, such as fast-growing aspen, which have been sucessful in parts of the United States, are impractical in the north due to the short growing season. Direct solar energy, although plentiful in southern parts of the Northwest Territories in summer, is almost absent in the winter when energy demands are highest.

Much of Canada's north, however, has one alternate energy source that remains virtually untapped — wind. Exploiting wind as an energy source is currently generating world-wide interest. In the Northwest Territories, there is a growing awareness that in some areas wind is indeed a viable energy source.

1.2 BRIEF HISTORY OF WIND POWER

Extracting energy from wind is not, of course, new. For centuries, wind was the main power source for ships, for the grinding of grain, and the pumping of water. Only within the last century or so with the advent of steam power and fossil fuels, as more reliable and more convenient energy sources, has wind energy diminished in importance. When the first steam engines were introduced for industrial purposes, such as grain grinding and factory operations, some people remained convinced that steam would never replace wind as the main energy source for such applications. Today we have come full circle. Many people cannot envisage wind providing a significant fraction of society's energy needs. Yet, the basic principles for extracting energy from wind have been known for about seven centuries; the basic physics and quantitative principles have been known for over 50 years.

During the past century windmills were a common sight in most parts of Europe, especially Holland and England. On this continent, between 1870 and 1930, about 6.5 million windmills were in use. The number of windmills currently in use has dropped to about 175,000 (Halacy, 1977). Most windmills in the USA and Canada were the smaller variety used to pump water for cattle. Since the turn of the century, aero-generators were developed to harness the wind for the production of electrical energy. Small wind machines producing cheap, but unreliable, electrical energy were a common sight in rural USA and Canada in the 1930's.

The introduction of rural electrification programs in the 1930's and 1940's rang the death knell for wind as a significant energy source on this continent. Government subsidies to utility companies enabled them to extend their services to rural areas, so that today few rural areas are not served by electrical utilities. Initially, the cost to the consumer may have been somewhat higher than his wind machine but it was worth it in terms of convenience and reliability.

During this period most conventional wind machines, such as the Jacobs or Wincharger, were designed for 6, 12, 24, or 32 volt DC operation. Although this was satisfactory for things such as lighting, most appliances were designed for 110 volt AC. Thus, the homeowner was faced with the choice of purchasing an expensive (and generally inefficient) inverter, to produce 110 volt AC from the lower voltage DC, or scrapping his wind generator in favour of the utility company. In most cases, the choice was an easy one.

This trend toward discarding the small and medium-sized wind machines was general throughout the world. In a few countries, however, where rural electrification is impractical, the technology relating to the smaller wind machines continued to develop. In Australia, which has vast remote or isolated areas, a viable wind-power industry has continued. Similarly, in Switzerland, harnessed wind provides energy to remote mountain resorts. Thus, "off-the-shelf" wind-power equipment has been available in these countries for the past 30 or 40 years. This explains why Australian and Swiss suppliers rank high as far as wind-energy technology is concerned.

Some form of wind energy has been used in the north for many years. The earliest explorers came in sailing ships. Nansen, in his polar explorations, built a wind-driven dynamo and in 1897 used it to provide electric lights for his polar camps. Electric lights were not then commonplace even in many larger cities in the south. Admiral Byrd used a Jacobs wind generator in the Antarctic and years later his son found the machine still in working condition.

In the Northwest Territories, a few enterprising individuals have used wind machines in remote areas with varying results. The Hudson's Bay Company used a Jacobs generator at Holman Island for about three years. The Joint Air Weather Stations in the early 1950's experienced a fruitless attempt to harness the wind. Thirty-two volt Wincharger generators erected at Mould Bay and Eureka were soon abandoned — probably due to the relatively low wind-energy potential at these sites (Chorney, 1981). A recent, but more successful effort was a joint venture by the At-

mospheric Environment Service and Canadian Marine Drilling. A floating automatic weather station installed in the arctic icepack (Grauman, 1977) was powered by a generator with a vertical-axis rotor (Plate 1). The system worked satisfactorily for over a year. It continued to send weather information until it floated to a point on the Siberian side of the pole where its signals could no longer reach the GOES satellite.

Plate 1. Wind-powered automatic weather station in the Beaufort Sea June 12, 1976. (Photo courtesy Glen Leal, Atmospheric Environment Service).

2. Basic Principles

2.1 DEFINITIONS AND TERMINOLOGY

Wind-energy technology, like other branches of technology, has its own language. Regrettably, however, writers in this field have not agreed on units and terminology. This may be due, in part, to the fact that wind-energy technology embraces other technologies, each of which brings its own terminology to the wind-energy field. An example of these differences in wind-energy literature is wind-speed units. These units may be expressed as metres per second (ms^{-1}), kilometres per hour (km/h), miles per hour (mph) or knots.

In this report every effort is made to keep the terminology and units simple and consistent. Where alternate units are used, a conversion factor is included in the discussion. The wind-related units frequently used in this report are:

wind speed expressed in kilometres per hour (km/h),
wind power expressed in watts or kilowatts (W or kW), and
wind energy expressed in kilowatt hours (kWh).

Several technical terms and concepts that appear repeatedly in this and other reports on wind energy are reviewed in this section.

1. Energy — Power: These two terms are basic to an understanding of wind-energy technology. Yet, they cause great confusion and some writers use them interchangeably. The distinction between the two is important.

   The formal definition of energy is the ability to do work, whereas power is defined as the time rate at which work is done (i.e., the rate at which energy is consumed). The relationship between energy and power is analogous to the familiar relationship between distance and speed:

   Distance (km) = Speed (km/h) x Time (h)
   Energy (kWh) = Power (kW) x Time (h)

2. The swept area: The reader has probably at one time or another used a fan to cool a room. From this experience it is evident that a large fan will produce more wind than a small one. The large fan also requires more energy to perform its task — it has a higher power rating. The reverse is also true. That is, if the wind turns a fan or a windmill, the larger the rotor or blade, the more energy it can produce. This is a fundamental principle in wind-energy applications. The energy that can be extracted from the wind depends on the swept area. It follows that wind energy is often expressed as kilowatt hours per square metre (kWh/m^2), and wind power as watts per square metre (W/m^2).

3. Wind speed: At first glance, the concept and definition of wind speed should be simple and straightforward. Not so! The difficulty arises when we come to the actual measurement of wind speed. Should it be measured continuously or should periodic samples be taken? Practical considerations make periodic sampling, generally once per hour, the most common. Both wind speed and direction are measured by taking a one-minute mean just prior to the hour. This one-minute mean is assumed to be representative of the wind for the previous hour.

Mean daily wind speed is defined as the total daily windrun divided by 24. (Windrun is the total number of kilometres of wind that pass the station during a given period of time.)

The mean monthly wind speed is defined as the total windrun for the month divided by the total number of hours in that month.

The mean annual wind speed is defined as the mean of the monthly wind speeds.

2.2 ASSESSING SUPPLY OF WIND ENERGY

2.2.1 Theoretical Power in the Wind

The power, P, contained in a moving air column can be expressed by the relation:

$$P = \tfrac{1}{2}\rho AV^3 \quad \ldots\ldots (1)$$

where P is the power
A is the cross-sectional area of the moving column
V is the wind speed
ρ is the air density

The air density, ρ, depends on atmospheric pressure and temperature and thus fluctuates from hour to hour as well as season to season. The wind speed, V, may vary continuously. A true evaluation of P from the above expression, then, becomes somewhat difficult.

In practice, equation (1) is integrated over a suitable time frame in order to obtain total energy — the quantity in which we are really interested. Thus in terms of "energy available" equation (1) becomes:

$$E = \sum_{t=0}^{T} \rho_t A V_t^3 t \quad \ldots\ldots (2)$$

Hourly values of temperature, pressure, and wind speed are available for most weather stations in the Northwest Territories. To calculate the energy available, E, we must calculate the energy for each individual hour and sum these values over a month or year. This of course, is a tedious process and can be done efficiently only by a computer.

Since in Equation 1 the changes in V^3 are large in comparison with ρ, this latter quantity is often treated as a constant by introducing standard values for pressure and temperature (i.e., at standard pressure, 101.3 kPa, and standard temperature, 0°C, ρ = 1.2923 kg m^{-3}). By introducing proper units, we obtain:

$$P = 1.38 \times 10^{-6} V^3 \quad \ldots\ldots (3)$$

where V is in km/h
P is in kWh

Expression (3) can be used to determine the approximate energy that would be produced over one hour.

2.2.2 Wind Energy in Relation to Wind-speed Classes

Since wind energy depends on the cube of the wind speed, the major contribution to the true wind energy is from winds of higher speeds. For most regions in the Northwest Territories, the major contribution to the wind-energy profile is from speeds in the 30 to 50 km/h class. A fairly typical data set showing the relationship of available energy to speed classes is shown for Cambridge Bay (Table 1).

Although the winds equal to or greater than 30 km/h produce over 80% of the annual energy, the winds in these classes blow only about 25% of the time. This underscores the principle that a viable wind-energy proposition needs a substantial time with winds in excess of 20 km/h.

Speed Class	0	1-5	6-10	11-20	21-29	30-39	40-49	50-59	60-68	69-75	75
Hours in Class	319	422	1151	2765	1930	1389	589	188	33	11	3
Energy in Class	0	0.3	9	150	386	695	619	376	105	53	19

Table 1. Annual frequency distribution and available energy (kWh) in various wind-speed classes (km/h) for Cambridge Bay. (Environment Canada, 1976)

2.2.3 Actual Energy Available from the Wind

The energy calculated from equation (2) in Section 2.2.1 represents the energy in the moving air, rather than the amount that can be extracted by a wind rotor. According to theoretical models, the maximum amount of energy that can be extracted from the moving air is about 60% of the available energy. This fraction is usually referred to as the Betz co-efficient (0.5926).

Wind rotors and electrical generators are not perfect and when losses due to these inefficiencies are taken into account, the maximum recoverable energy drops to about 20 to 30% of the gross wind-energy flux.

2.2.4 Variation of Wind with Height

The general principles governing the variation of wind speed with height are well known. Wind is retarded by friction with the surface over which it blows. Generally, the rougher the terrain the greater the speed loss due to friction. Normally, wind increases with height from the earth's surface to about 1,500 m. The variation of wind with height is expressed by the power law:

$$V_2 = V_{10} \left(\frac{H_2}{H_{10}}\right)^{1/n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

where V_2 is the wind speed at height H_2

V_{10} is the wind speed at height H_{10} (the 10 m standard anemometer height).

n is a constant generally near 6.

The value assigned to N can be a problem as it depends on local characteristics such as vertical temperature gradient, surface roughness, and turbulence. Values around 6 or 7 are usually quoted for rolling terrain. A value of 7 should give reasonable results for most of the Northwest Territories.

In practical terms, the power law with a 1/7 exponent translates to an increase in wind speed of about 10% if the height is doubled from 10 m to 20 m. This may seem trivial when considering the expense and trouble of erecting a 20 m tower rather than one of 10 m. However, it must be remembered that the increase in energy depends on the cube of the wind speed. Thus, the modest increase of 10% in wind speed translates to about 35% increase in energy. The use of higher towers, especially in areas with marginal wind-energy potential, may be worth considering.

3. Wind-Energy Technology

3.1 INTRODUCTION

This chapter gives a brief overview of the basic principles of wind-energy technology. Wind-energy conversion systems (WECS) vary considerably in appearance and complexity, yet the basic operating principles are the same. The kinetic energy of the wind stream is converted to a rotating or oscillating motion that can do useful work. In the simplest WECS, the rotary motion is used to drive mechanical devices such as pumps. The most common approach, however, is to change the rotary motion to electrical energy. System designs vary from the small do-it-yourself to the multi-megawatt systems with rotors having diameters approaching 100 m.

3.2 CLASSIFICATION

Wind-energy conversion systems can be classified in various ways. One method is to classify them on the basis of size (Royal Architectural Institute, 1979), another on the basis of rotor design (Hawrelak et al., 1976).

3.2.1. Small Domestic Units

These have ratings up to 10 or 12 kW and are intended to service a dwelling or small commercial establishment. Several units meeting such needs are available commercially and "off-the-shelf" units are now becoming fairly common. The outstanding example, of course, is the venerable Jacobs two-bladed horizontal axis type, which is no longer in production.

Installation and operation of such units might well be undertaken privately or in cooperation with one or two other users.

3.2.2. Intermediate Units

These have ratings up to 200 kW and would serve several private dwellings or a small community. Installation and operation would require some measure of government, cooperative, or utility company support. "Off-the-shelf" availability is a few years away, but prototypes are being tested in various parts of the world.

3.2.3. Large Units

Units with megawatt ratings are currently being developed in several parts of the world. NASA, in the United States, has an active research program relating to such machines. Large units of such rating would provide a major contribution to a regional power grid and would, of course, require substantial initial government support. Several aerospace firms are currently bringing a background of advanced technology into this field.

3.3 System Components

Harnessing the wind for domestic or commercial energy applications consists essentially of four steps:

1. Energy extraction
2. Energy conversion
3. Energy storage
4. Energy use

Figure 1 summarizes the current approach to these four steps. Conversion devices such as direct heat churns and pumps are currently inefficient and development is proceeding. Battery storage, although expensive, is the most efficient at the current level of technology. However, this type of energy storage is not compatible with most of today's electrical equipment, which requires 110V or 220V AC. The DC battery current must be converted to the higher voltage AC by means of an inverter. The high cost and poor performance of inverters contributed to the decline of wind-energy systems 40 years ago. Tremendous improvements in inverter efficiency have been achieved during the past few years, but the cost is still regrettably high.

A system with dual-energy storage has been suggested by Eldridge (1975). Storage batteries are used to supply the primary energy storage (Figure 2). When they are fully charged, additional energy from the wind machine is diverted to a resistance coil which heats water. The batteries are used to operate appliances and lights, whereas the hot water can be used for space heating.

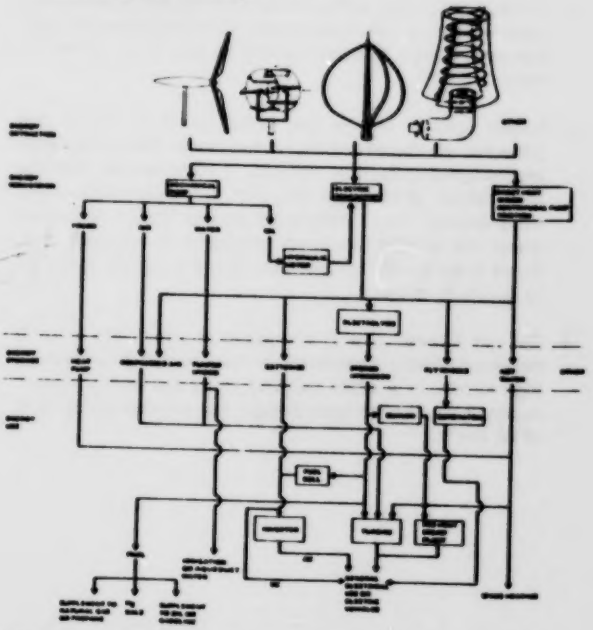


Figure 1. Schematic of various wind-energy conversion systems (from Eldridge 1975).

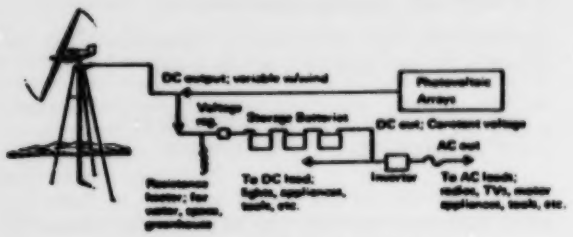


Figure 2. Schematic of dual-purpose system suitable for domestic applications (from Eldridge, 1975).

The length and frequency of "no charge" periods (i.e., periods when the wind is too light to activate the wind machine) are important factors in determining the capacity of a storage system. This report has graphs that should be useful in identifying such periods (Chapter 5).

3.4 WIND-RELATED SPECIFICATIONS OF WECS

Three wind speeds are usually included in the specifications of WECS (Figure 3).

1. Cut-in Speed: This is the lowest wind speed at which the rotor will turn to produce energy. Cut-in speeds vary with machine design but are usually in the 10 to 15 km/h range.

2. Rated Speed: This is the wind speed at which the generator produces the advertised power. Most machines are designed to feather the rotor in some way so that the rotor rotates at constant rpm with winds above the rated wind speed. Thus, with wind speeds above the rated speed the system produces energy at a constant rate. Rated speeds vary considerably, but are usually in the 30 to 50 km/h range.

3. Cut-out Speed: This is the speed at which the rotor is designed to stop completely in order to avoid damage by high winds. It is often referred to as the furling speed. Again, it varies with rotor design, but is generally upward of 60 km/h.

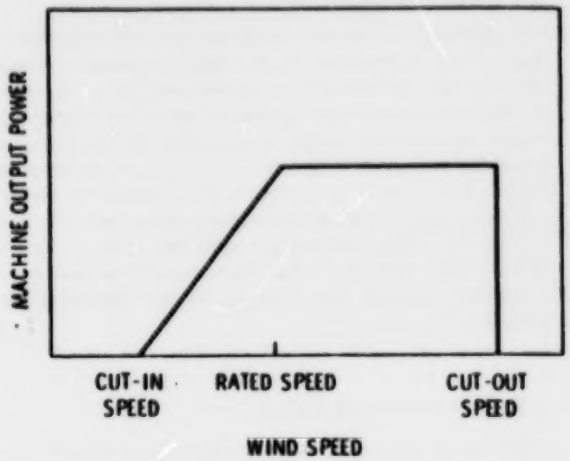


Figure 3. Typical power-output curve for a modern wind turbine generator (from World Meteorological Organization, 1981).

3.5 SPECIAL HARDWARE CONSIDERATIONS FOR ARCTIC ENVIRONMENTS

Hardware designed and tested in southern Canada is often unsuited to arctic conditions. Certain precautions must be taken in the selection of a WECS to ensure that the unit will operate satisfactorily in the north.

3.5.1 Logistics

Perhaps the logistics of installation should be a first consideration for any WECS. The weight of the aero-generator may create problems, so the purchaser should ensure beforehand that he has the means to mount the machine at the intended height and place. Logistical problems are very real in the Northwest Territories and may well limit the size of systems.

3.5.2 Lubrication

Low winter temperature in the Northwest Territories can create special lubrication problems. This may be especially true of equipment purchased from countries with a warmer climate. In parts of the Northwest Territories the rotor may sit idle for several days at temperatures around -40°C. What effect will this have on the start-up speed when the wind resumes?

3.5.3 Hardware Components

Modern instrument manufacturers use new products, such as plastics, extensively. Whether these plastic components which function satisfactorily in southern Canada, can withstand the rigors of the arctic environment is not known.

3.6 WIND-ENERGY LITERATURE

There has been a veritable explosion of information and literature in the wind-energy field during the past few years. Several special reports have been prepared for or by various government agencies in Canada. These are good sources of information for anyone seriously contemplating a WECS installation in the Northwest Territories. A recent publication by the World Meteorological Organization (1981) is an excellent source of background information for the engineer, meteorologist and the layman. This report, which is especially attractive to a wide range of readers, offers very practical advice on almost all aspects of wind utilization.

3.6.1 General Information Source on Wind Energy and Applications

Solar and Wind-Energy Information Centre
Alberta Research Council
5th Floor, Terrace Plaza
4445 Calgary Trail South
EDMONTON, Alberta
T6H 5R7

3.6.2 Basic Reference Dealing with Meteorological Aspects

Meteorological Aspects of the Utilization of Wind as an Energy Source
Published by: The Secretariat of the World Meteorological Organization, Geneva, Switzerland.

3.6.3 Publications Dealing with Hardware

Brown and Warne (1975)
Sandwell Beak Research Group (1979)
Royal Architectural Institute of Canada (1979)
Hawrelak et al. (1976)
Eldridge (1975)

The first four listed are Canadian reports and deal with hardware relating to Canadian applications (but not specifically to the Canadian north). The first two have extensive information on hardware manufacturers, distributors, specifications, and prices.

3.6.4 Publications of Popular or Do-It-Yourself Nature

Cheremisinoff (1976)
Clews (1975)
Heckleman (1974, 1975)
Sullivan (1976)

4. Wind-Energy Climatology of the Northwest Territories

4.1 INTRODUCTION

This chapter presents the wind-energy patterns in the Northwest Territories on both a geographical and seasonal basis. Fourteen wind-energy maps based on historical wind data have been prepared to meet this objective. These maps are not intended to meet the needs for a detailed design of a WECS. Rather, they provide the basic data required for a first estimate as to whether the wind energy in any particular area in the Northwest Territories is sufficient for serious consideration of a WECS.

4.2 CLIMATIC CONTROLS AND COMPLEXITY OF WIND PATTERNS

The climate of any area is determined by physical factors usually referred to as climatic controls. These are discussed in most textbooks on climatology. In the Canadian Arctic, two climatic controls induce tremendous complexities on the wind patterns. These are the nature of the underlying surface and topography.

4.2.1 The Underlying Surface

Unlike southern parts of the North American continent, the earth's surface over most of the Northwest Territories is constantly undergoing changes. The land mass has seasonal changes from snow-covered to snow-free. The ocean surface goes from open water (or partially open water) in the late summer to ice-covered with ice ridges and open leads in winter. In winter the land mass changes as snow drifts and piles up in response to migrating weather systems. These changes are reflected in the wind patterns and tend to create marked wind differences, especially in coastal areas, during the open-water season.

4.2.2 Topography

Just as water is channelled by its stream bed, air is channelled by hills, valleys, and mountains. Winds tend to blow up and down valleys, and respond to surprisingly small variations in topography. A ridge only 50 to 100 m high may be sufficient to cause channelling effects that are climatologically significant.

Ripples are induced when flowing water encounters an obstacle in its stream bed. Similarly, lee waves are induced in an air stream that encounters an obstacle such as a hill or mountain barrier. These waves can give rise to anomalous and occasionally peculiar surface wind patterns downstream from the barrier.

The general wind patterns of any region are determined by the synoptic, i.e., day-to-day, weather systems that pass over the region. These general patterns though, are modified by the terrain to produce highly localized wind patterns. On eastern Baffin Island, for example, the winds blow predominantly up or down the fjords even though the synoptic pattern would often suggest winds at right angles to the fjords.

The Northwest Territories has vast regions where, due to complex topography, surface wind patterns are highly localized and differ tremendously from one locality to another — even over relatively short distances. This is often true of both speed and direction.

A topographical map of the Northwest Territories shows that areas with complex terrain include the Mackenzie Valley, Mackenzie Mountains, the Arctic Coast from the Yukon border to the vicinity of Coppermine, the eastern half of the Queen Elizabeth Islands, and Baffin Island. The topography of these areas suggests anamolous and highly localized wind patterns.

4.3 WIND-ENERGY MAPS OF THE NORTHWEST TERRITORIES

4.3.1 Data Base and Methods

The energy equation discussed in Section 2.2, shows that in order to determine wind energy the starting point is wind-speed data. The published wind data have summaries of monthly and annual averages of wind speed and wind direction. Frequency distributions of winds in various speed classes are available for a few of the main airport locations in the Northwest Territories.

The energy equation is valid only for instantaneous wind measurements, although hourly values can be used without introducing too great an error. Monthly or annual averages cannot be used in the energy equation. The broadest data base, however, consists of monthly averages.

In order to take full advantage of this data base, the mean monthly wind values must be converted to potential energy values. Environment Canada (1976) analysed hourly wind data for several Canadian stations and determined monthly and annual wind energy values in the wind classes between 10 km/h and 58 km/h. Lamont (1976) used this work as a basis to arrive at a regression equation relating mean monthly wind speed and mean monthly wind energy (Figure 100, Appendix). This regression, when applied to the stations of the Northwest Territories, works satisfactorily for most stations. It gives values too low for stations, such as Cape Dyer and Resolute, with a high frequency of winds in the classes above 58 km/h.

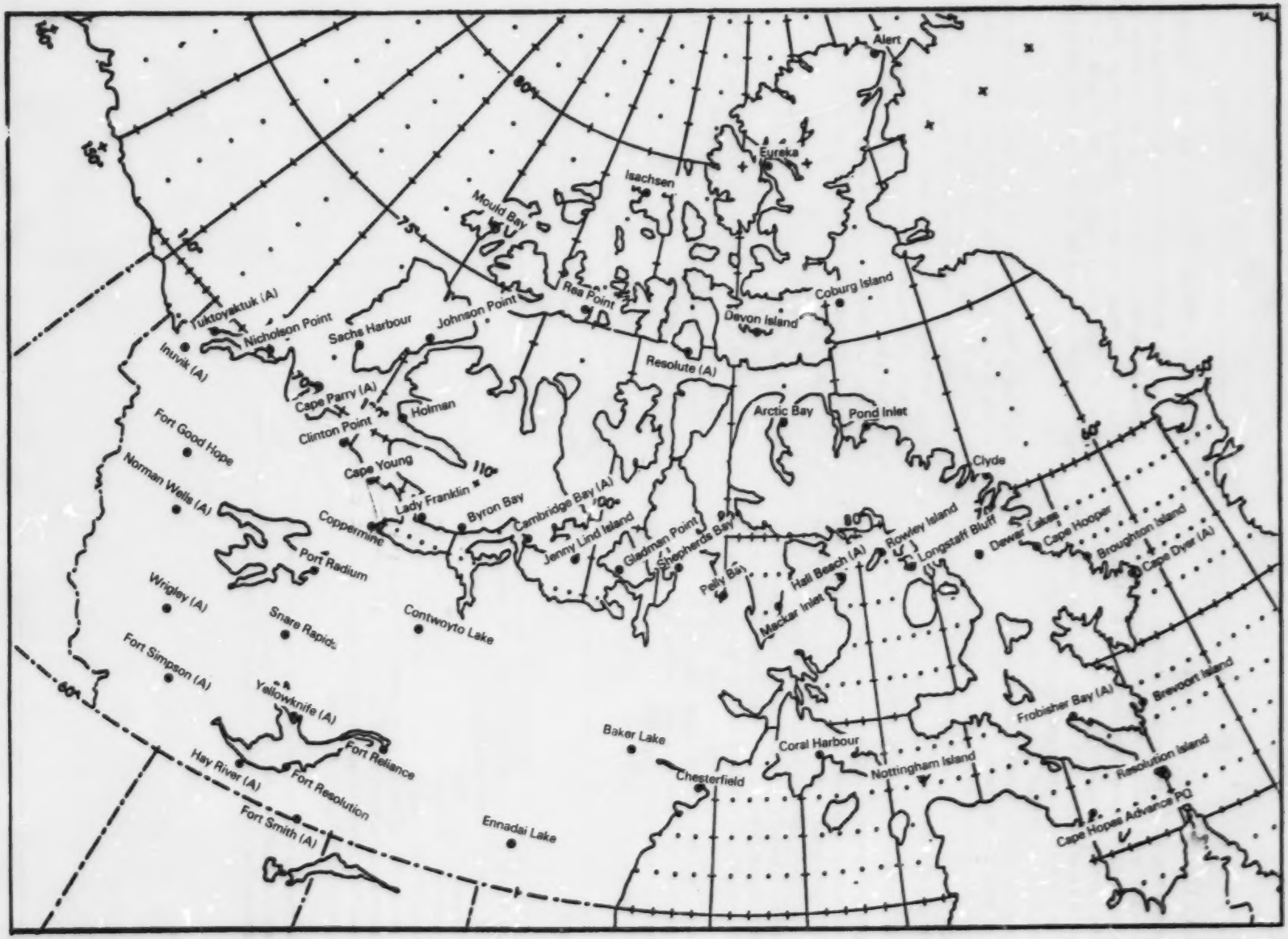


Figure 4. Location map showing stations with wind records used in this report.

4.3.1.1 Limitations of Data Base

The data base for the preparation of the wind-energy maps consists of mean monthly wind speeds from more than 50 stations in the Northwest Territories (Figure 4). These wind data are summarized in Table 2 (Appendix). As with most investigations of arctic regions, data are scarce. All data have not been collected over the same time period. Some stations have records for 30 years or more whereas only 1 or 2 years data are available for others. Analysis is difficult. The traditional statistical "normalizing" methods, where synthetic records for short-term stations are derived from stations with long-term records, did not work. The short-term records had to be treated subjectively.

4.3.2 Monthly and Annual Wind-Energy Maps

Maps showing wind-energy isopleths are often used to make an assessment as to feasibility of WECS on a geographical basis. Such maps have been prepared for Canada by Templin (1977), Sandwell Beak Research Group (1979), the National Research Council (1980), and the World Meteorological Organization (1981). These reports do not deal specifically with the Northwest Territories and thus give only the general wind-energy picture for Canada's northern regions. The maps included in this report (Figures 5 to 17) are based on as extensive a data base as was available. These maps show the energy field at a height of 10 m for winds between 10 and 58 km/h.

The steps followed in the preparation of these maps are as follows:

1. Beginning with the average monthly wind speed for a station (Table 2), the average monthly wind energy was calculated for each calendar month using Lamont's regression (Figure 100).
2. These values, with the Betz factor introduced, formed the basis for the monthly wind-energy maps (Figures 6 to 17).
3. The monthly values for each station were summed to determine the average annual wind energy and form the basis for the map in Figure 5. The calculated values are summarized in Table 3, Appendix.

These monthly and annual wind-energy maps are based on current, published wind data. The data base and calculations are independent of those used in Chapter 5 of this report.

4.3.2.1 Mean Annual Wind-Energy Map (Figure 5)

This map depicts the basic wind-energy climatology of the Northwest Territories. It shows, on a regional basis, the areas of low energy, such as the Mackenzie Valley, and the areas of high energy, such as the Keewatin. The topographical influences can be seen on Baffin island and Lancaster Sound.

The map is the best source of information for preliminary calculations and initial assessment of wind-energy applications in the Northwest Territories. The basic data have not been plotted, but are tabulated in the Appendix (Table 3) along with evaluations of those stations with known wind anomalies. The isopleths on this and the monthly maps represent energy values with the Betz factor already applied. Analysing such maps is necessarily subjective, especially in regions of complex topography and areas of known wind anomalies.

Striking features are:

1. The generally low values over the Arctic Ocean, the Mackenzie Valley and parts of Ellesmere Island.
2. The strong axis from east of Isachsen across central Victoria Island and then southeastward toward Baker Lake.
3. The strong zone in Lancaster Sound extending southeastward just off the east coast of Baffin Island. Also the strong zone in Hudson Strait.
4. The variable zone along the east coast of Baffin Island. In this area most reporting stations are located in sheltered fjords, so have very low values (Table 3). Adjacent headlands, however, likely have high wind-energy potential.

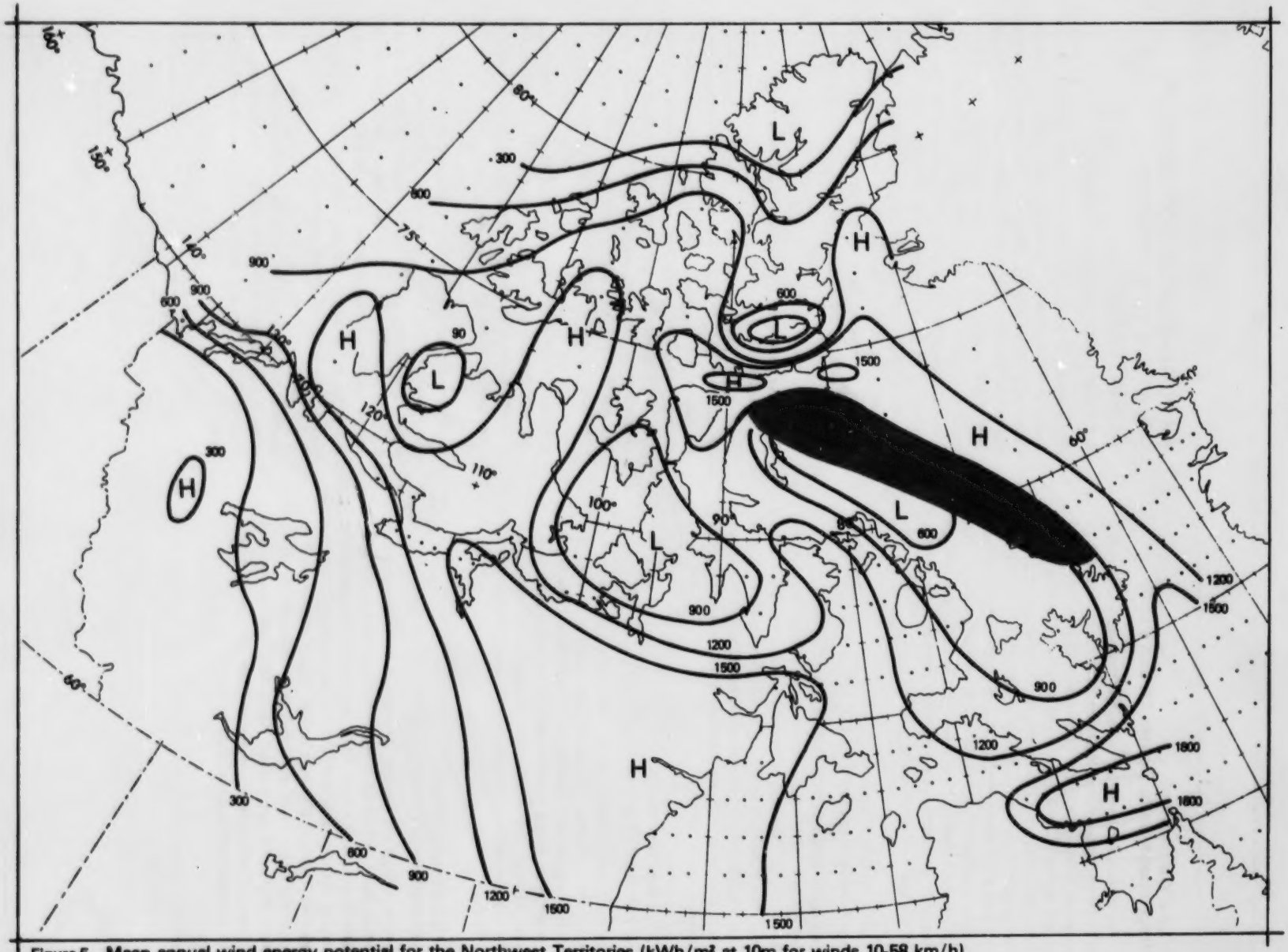


Figure 5. Mean annual wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

4.3.2.2 Winter Maps (December-March, Figures 17, and 6 to 8).

In this section and those to follow, the seasons are not defined in the traditional sense, but rather in terms of wind-energy potential. The winter maps, in general, follow patterns seen on the annual map. The very low values in the Mackenzie Valley are noteworthy. The main axis of the strongest energy flow is again from the west coast of Hudson Bay across Victoria Island and northward. The minor axis from Amundsen Gulf to southern Victoria Island is prominent as well. The high values extending from Baker Lake to Hall Beach are apparent. Weaker values along the DEWline east of Cambridge Bay are again evident.

4.3.2.3 Spring Maps (April-June, Figures 9 to 11).

Once again, the same basic pattern as in other maps persists. Low values continue along the Mackenzie Valley and a small area of higher values is evident over the Great Slave Lake area. The maximum over the Keewatin, however, has a lower value than on the winter maps and the DEWline values east of Cambridge Bay are considerably higher relative to the Keewatin maximum.

4.3.2.4 Summer Maps (July-August, Figures 12 and 13)

The same basic pattern persists, but a few changes are evident in the northwest. Mould Bay and Isachsen have higher values in comparison to other western stations. This change is in response to the summer shift of the storm track to the arctic latitudes. Lowest monthly energy values are evident over the Keewatin and highest along the DEWline east of Cambridge.

4.3.2.5 Autumn Maps (September-November, Figures 14 to 16).

Monthly values are highest for many sites. One significant feature is the shift of the maximum energy flow to the open water and coastal areas. Thus, the major axis, which for most of the year lies from around Churchill to Cambridge Bay and Resolute, has by October shifted eastward to lie along the coast of Hudson Bay and northward to Foxe Basin. The minor axis through Amundsen Gulf persists and highest monthly values are evident over the Beaufort Sea and southwestern coast of Banks Island.

4.4 WIND-ENERGY POTENTIAL IN RELATION TO SYNOPTIC CLIMATOLOGY

4.4.1 Seasonal Synoptic Patterns

The contrast in wind-energy potential between the western areas of the Northwest Territories and central and eastern portions is rather striking (Figure 5). The underlying reason for this is related to the synoptic climatology (i.e., the pattern of seasonal migration of pressure systems) of the arctic regions. Oceans, mountains and the vast snow and ice-covered surfaces all play vital roles in the development and dissipation of both high pressure cells and cyclonic storm centres. A student of arctic meteorology soon learns that the Mackenzie Valley and the Yukon are areas of cyclogenesis, whereas the eastern Northwest Territories, particularly the Baffin Bay area, are often referred to as the graveyard of cyclones.

According to Wilson (1973), from December to February a high pressure cell is common over the Yukon-Mackenzie areas and a trough in the Baffin Bay-Davis Strait areas. Thus, a northerly flow prevails over the central portions of the Northwest Territories. Baker Lake, Chesterfield and Isachsen have a high frequency of blowing snow, but winds over the Keewatin are generally higher than at Isachsen. Average mean sea level pressure charts for January show less gradient between Jenny Lind Island and Mackar Inlet than over Victoria Island and Coronation Gulf.

Cold pockets of air tend to stagnate in the area Queen Maud Gulf and Committee Bay areas in winter. High static stability in lower levels with poor coupling to winds aloft tends to keep surface winds generally low.

By March the cold high generally moves from the Yukon to the Beaufort Sea with a secondary centre between Fort Reliance and Baker Lake. This shift alters the wind direction over the western portions of the Mackenzie District with a higher frequency of southwesterly winds developing west of the arctic high. Wind speeds, however, do not increase significantly from the winter values.

Cyclonic activity is high in the Davis Strait and Labrador Sea areas in comparison with other areas in the Northwest Territories. The spring and autumn months produce frequent gales.

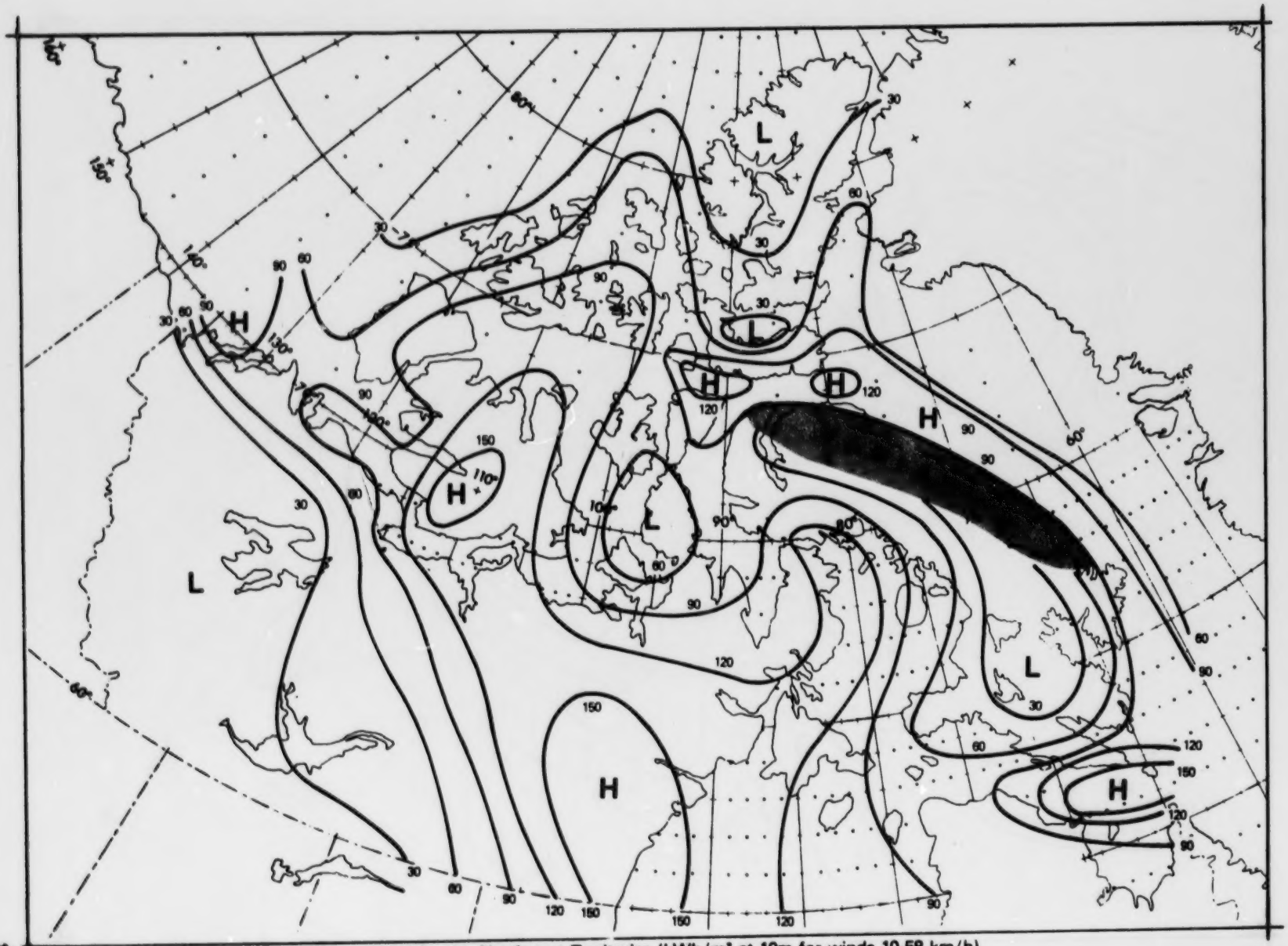


Figure 6. Mean January wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

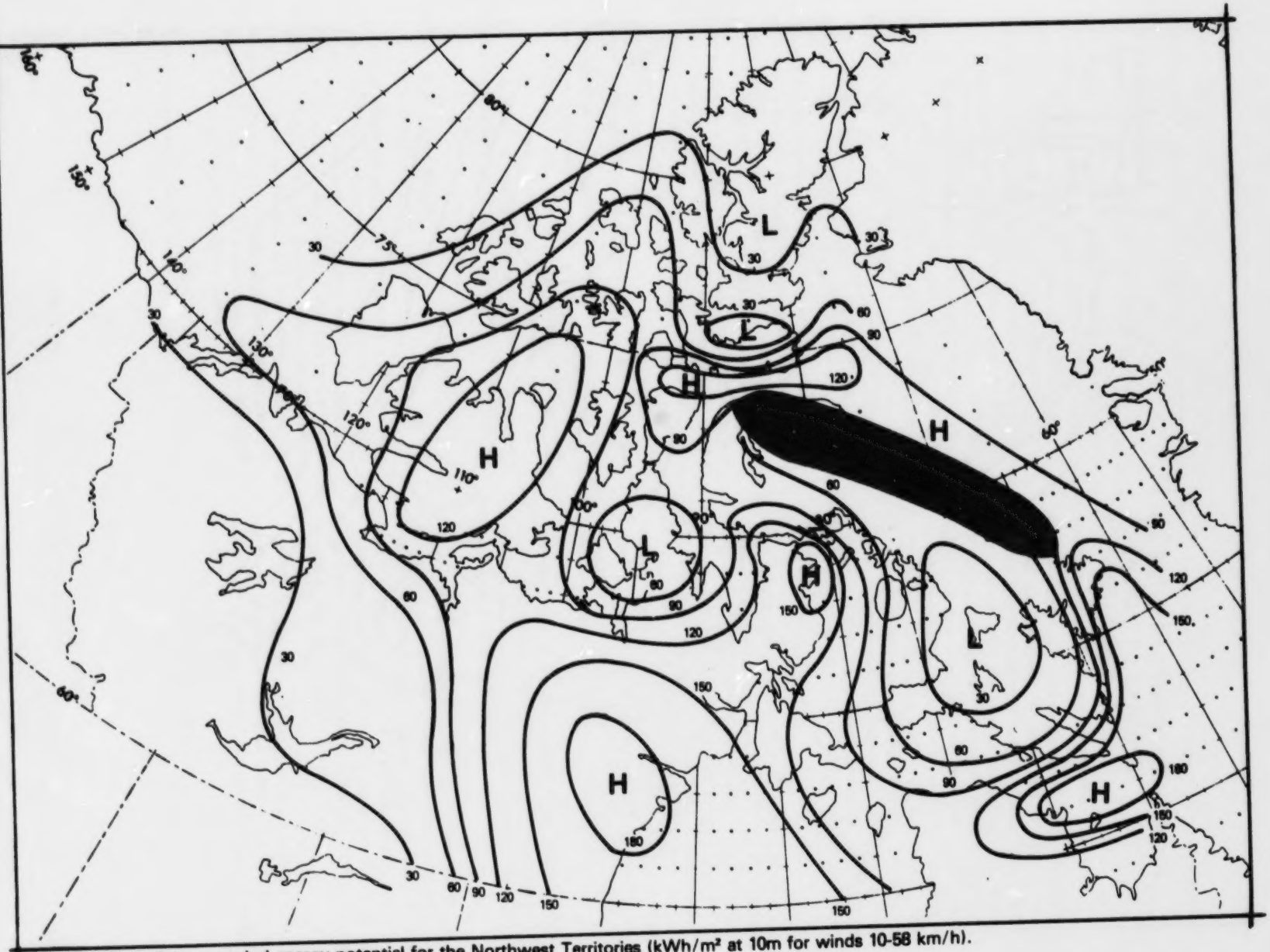


Figure 7. Mean February wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

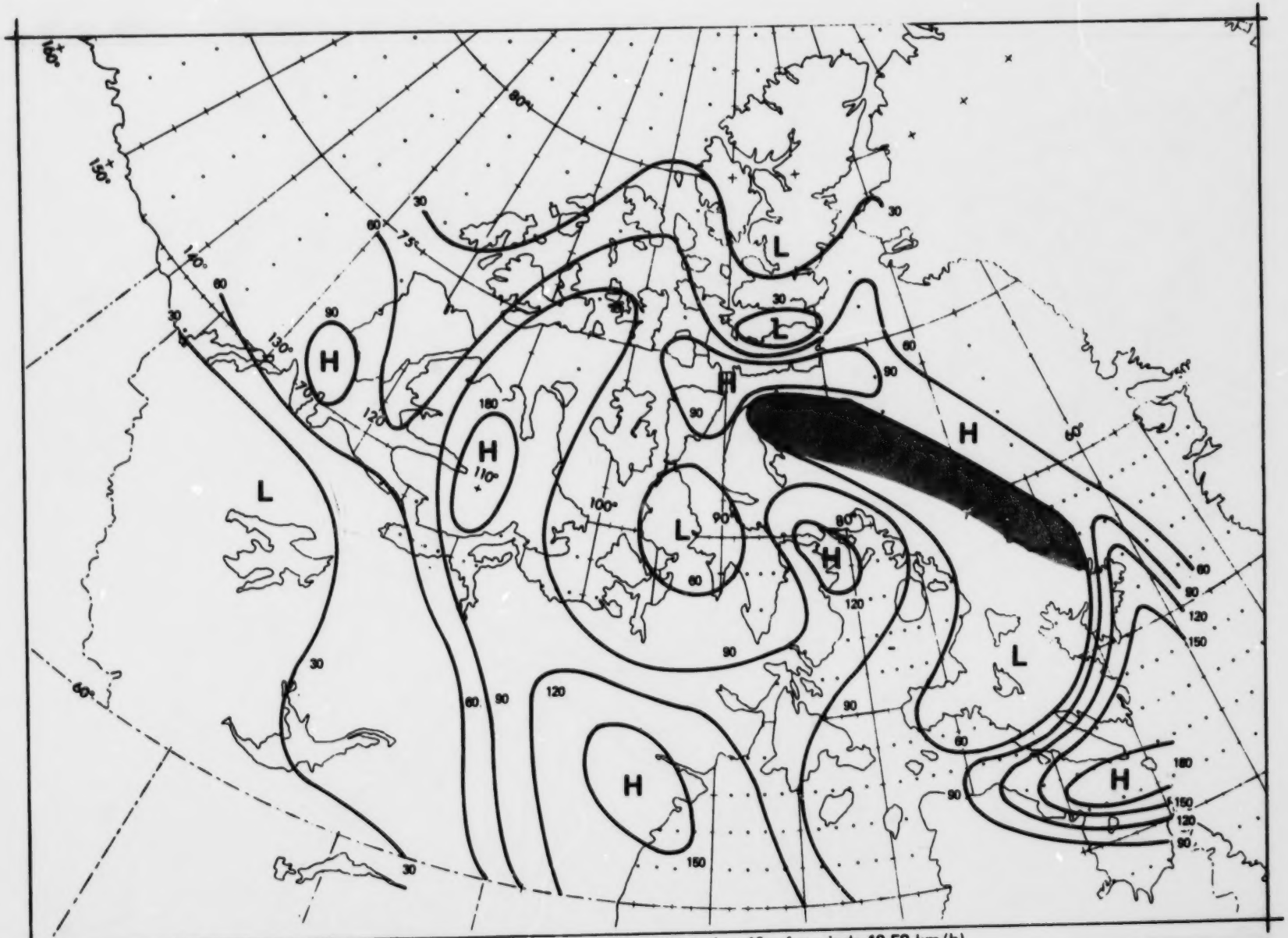


Figure 8. Mean March wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

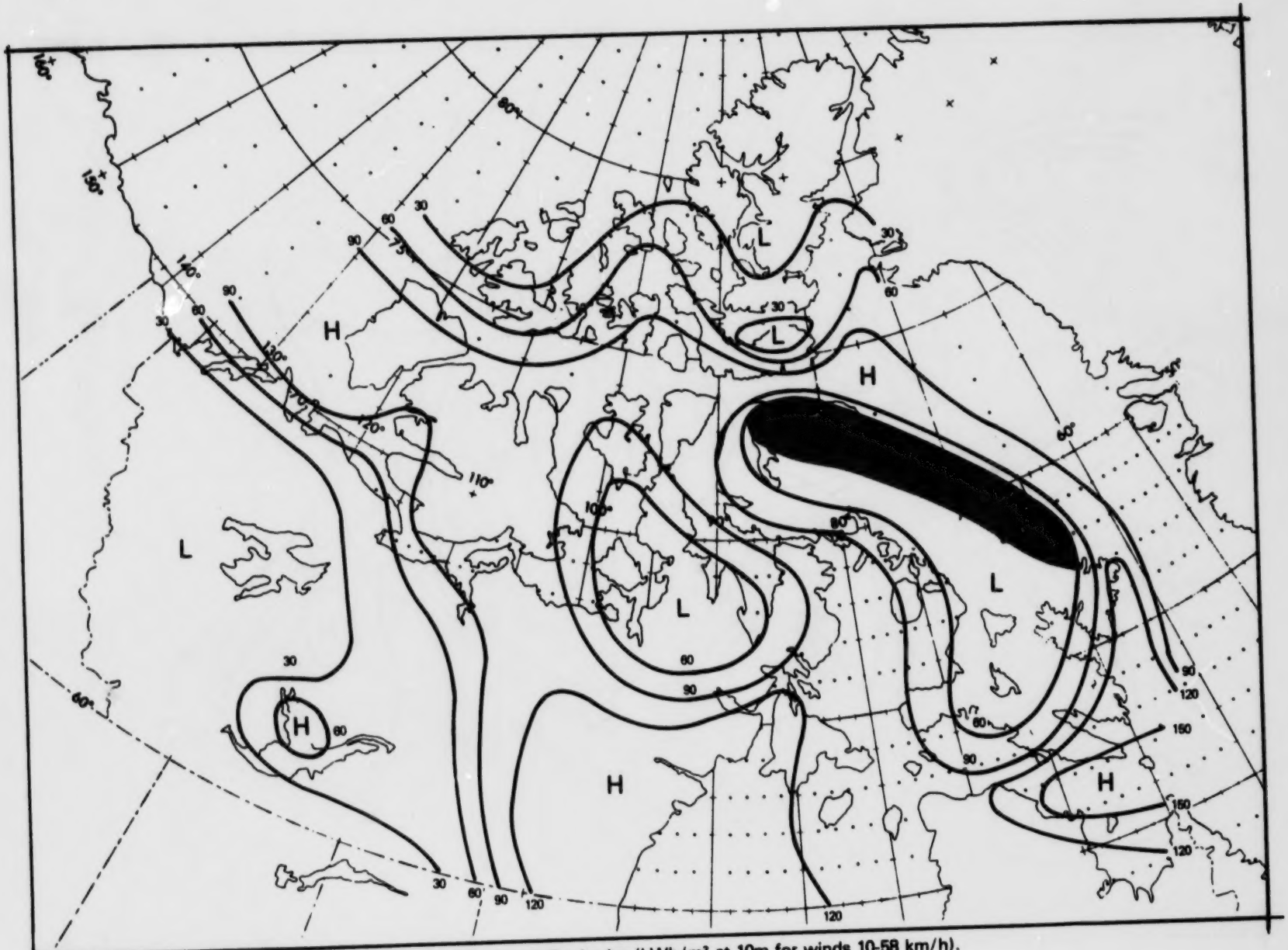


Figure 9. Mean April wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

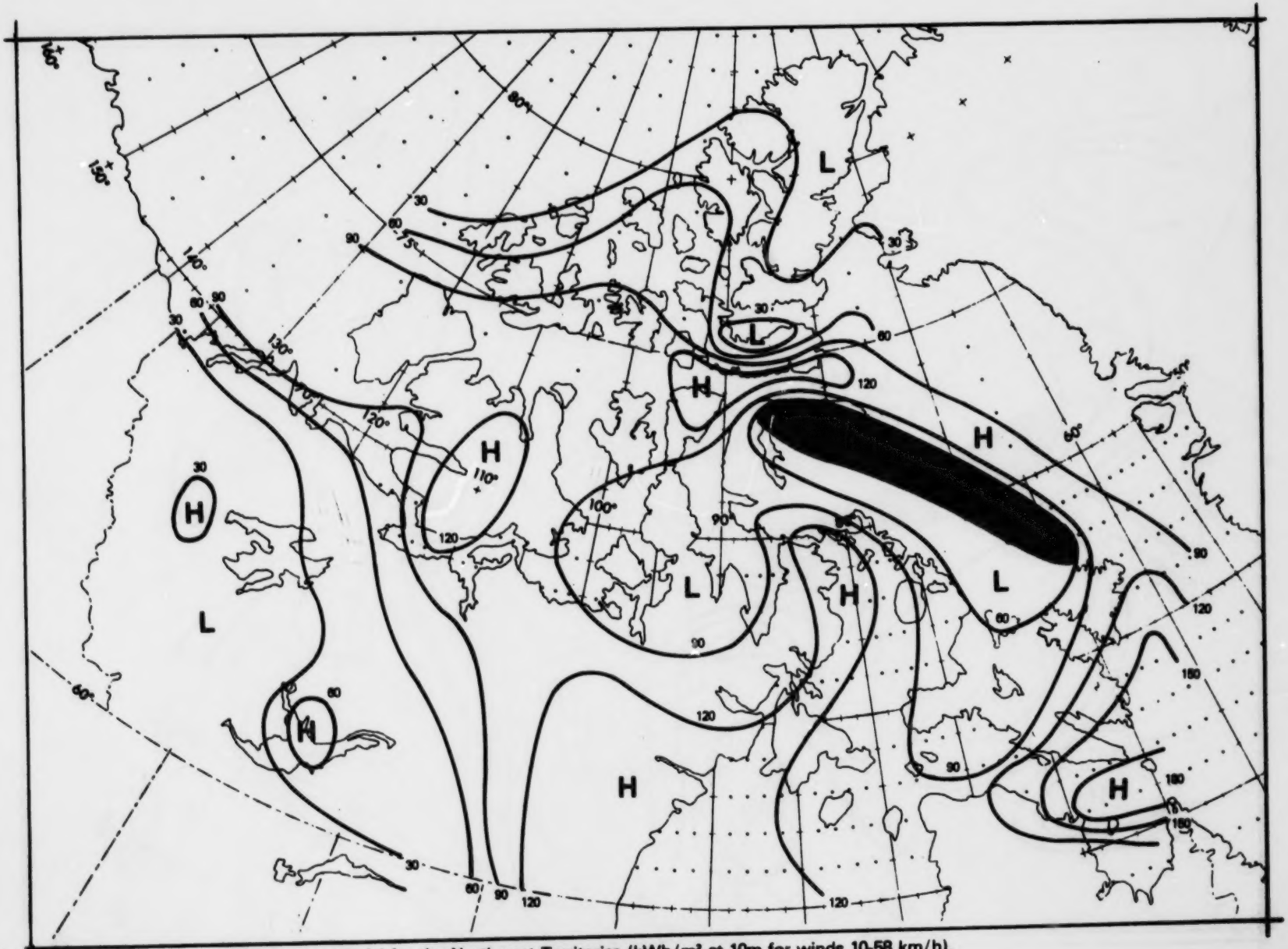


Figure 10. Mean May wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

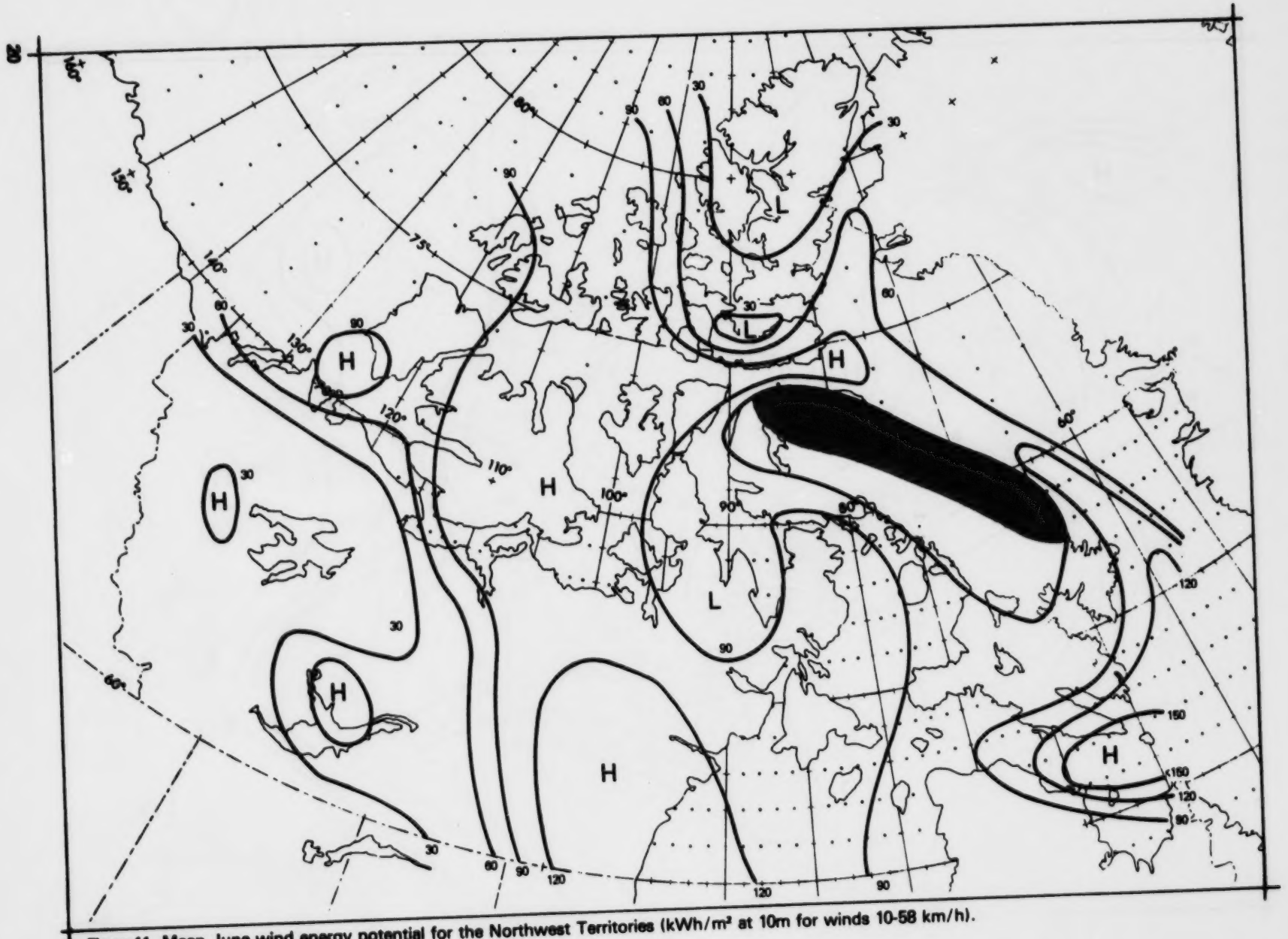


Figure 11. Mean June wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

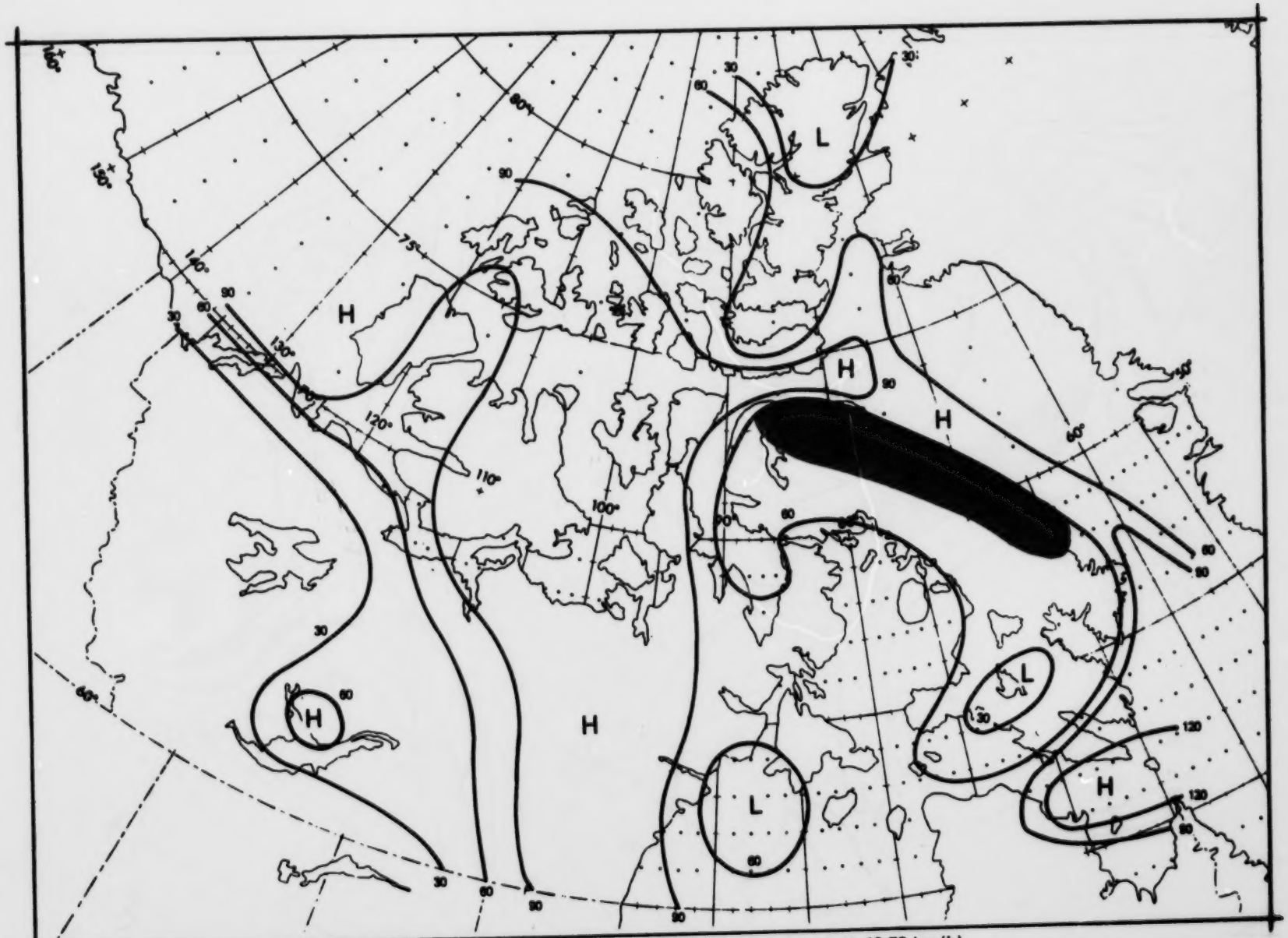


Figure 12. Mean July wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

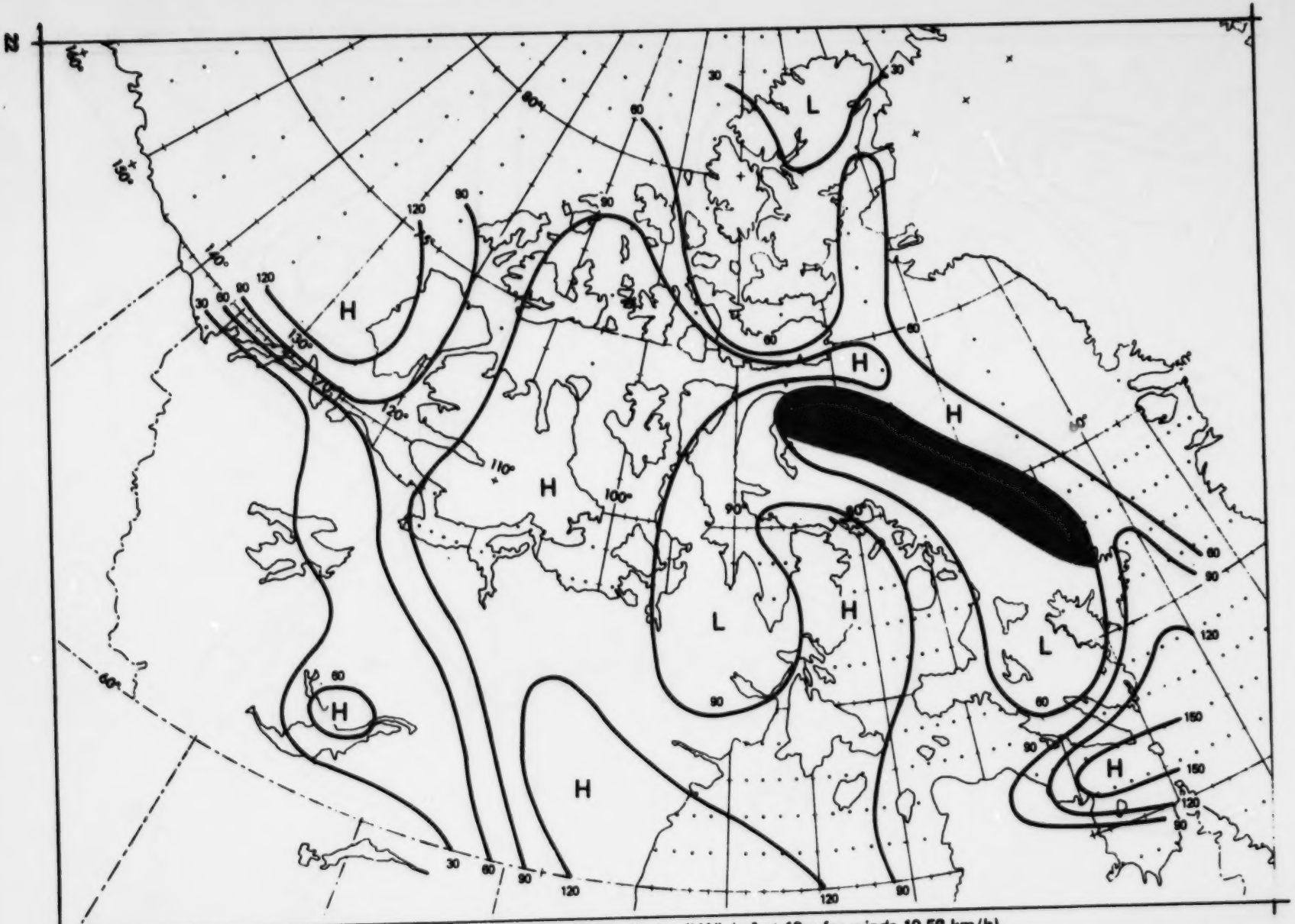


Figure 13. Mean August wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

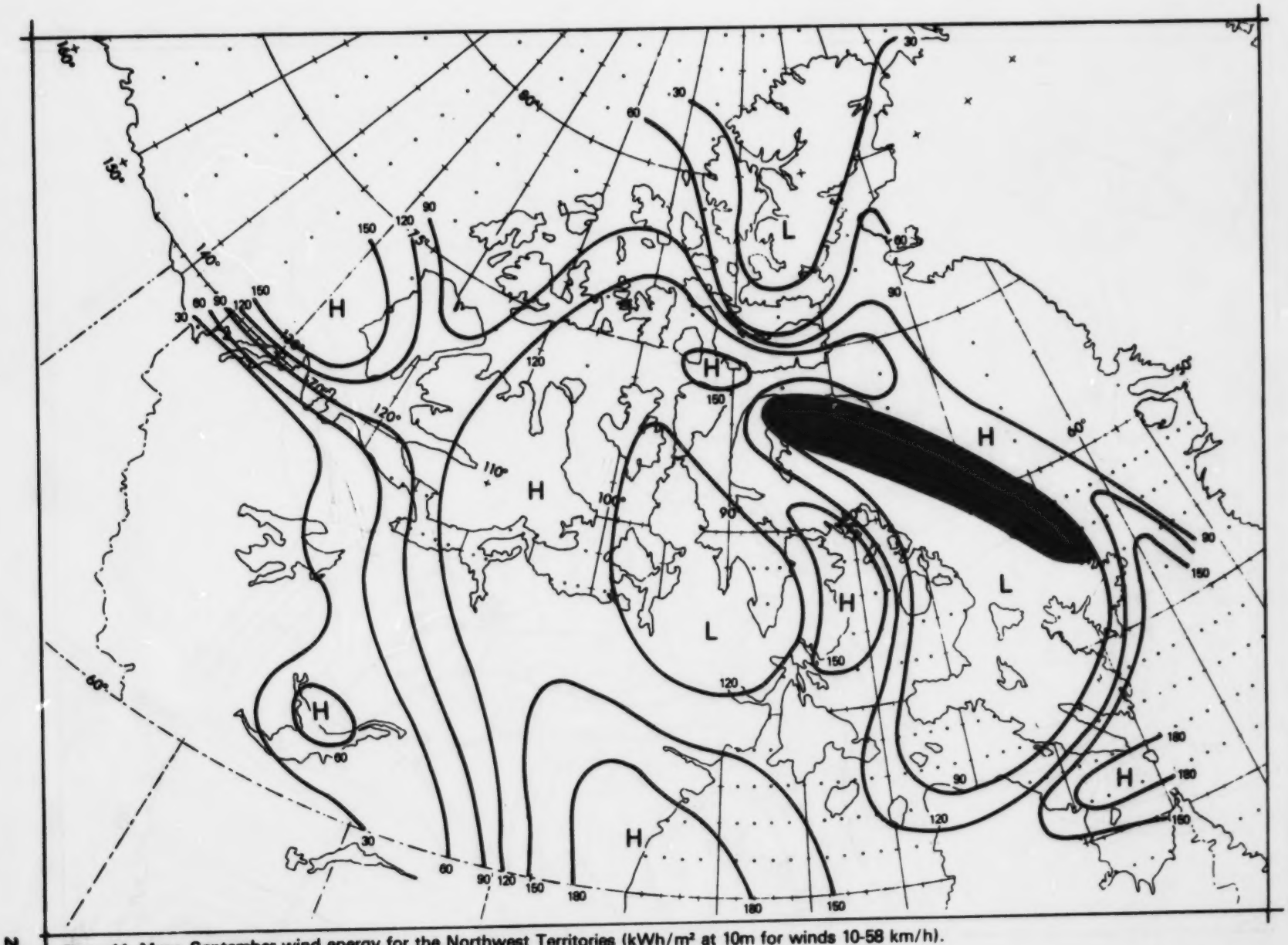


Figure 14. Mean September wind energy for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

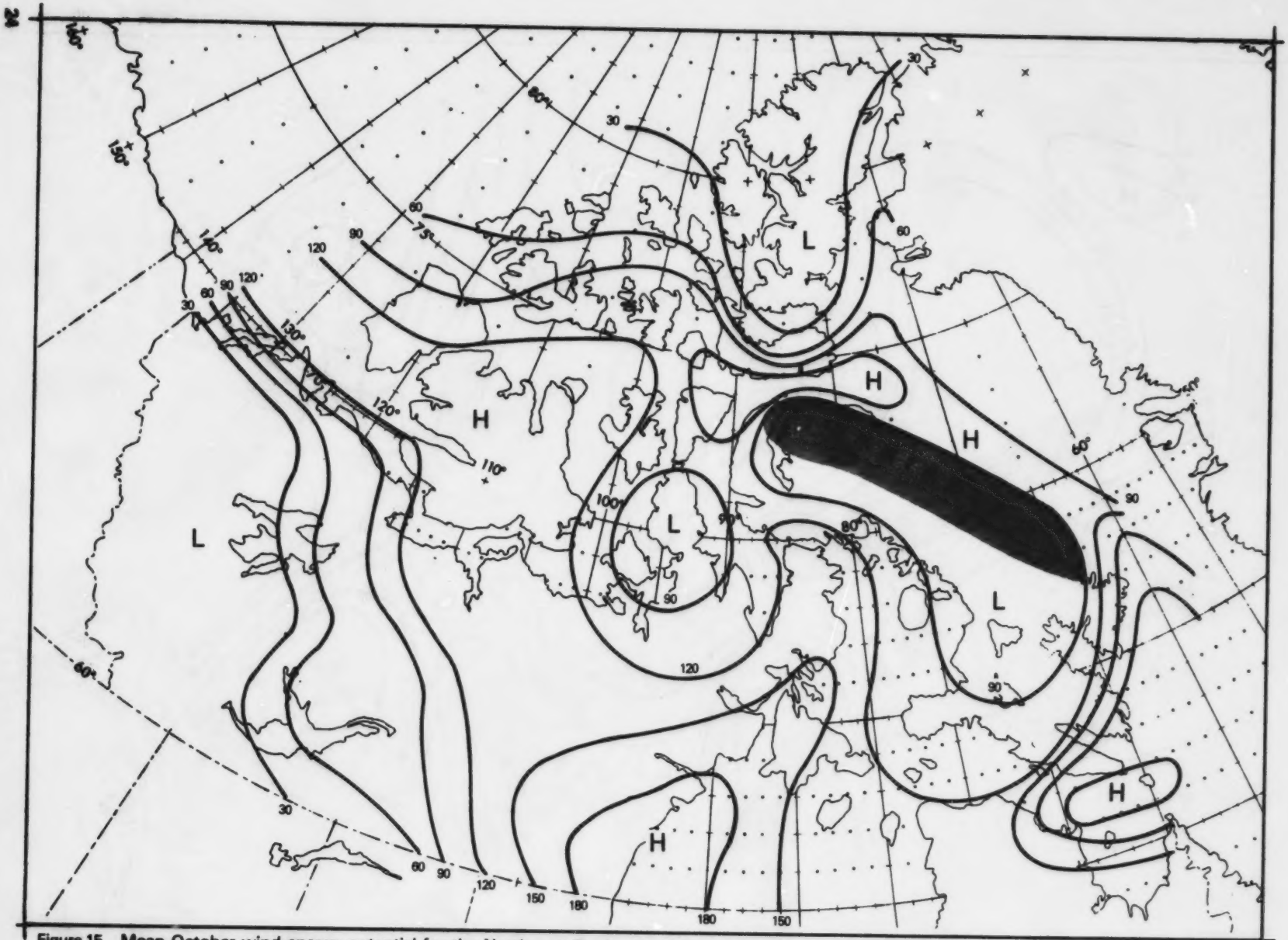


Figure 15. Mean October wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

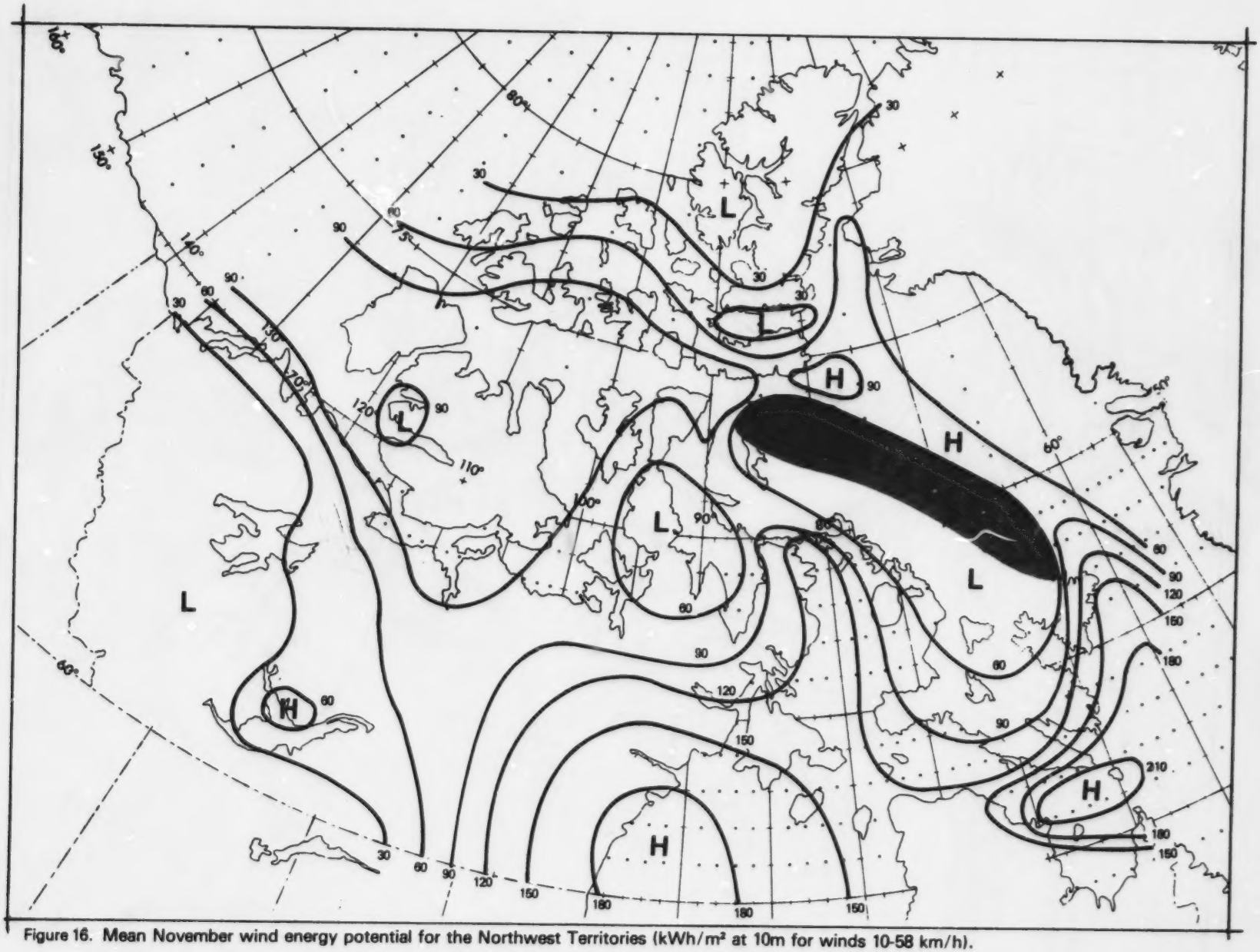


Figure 16. Mean November wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

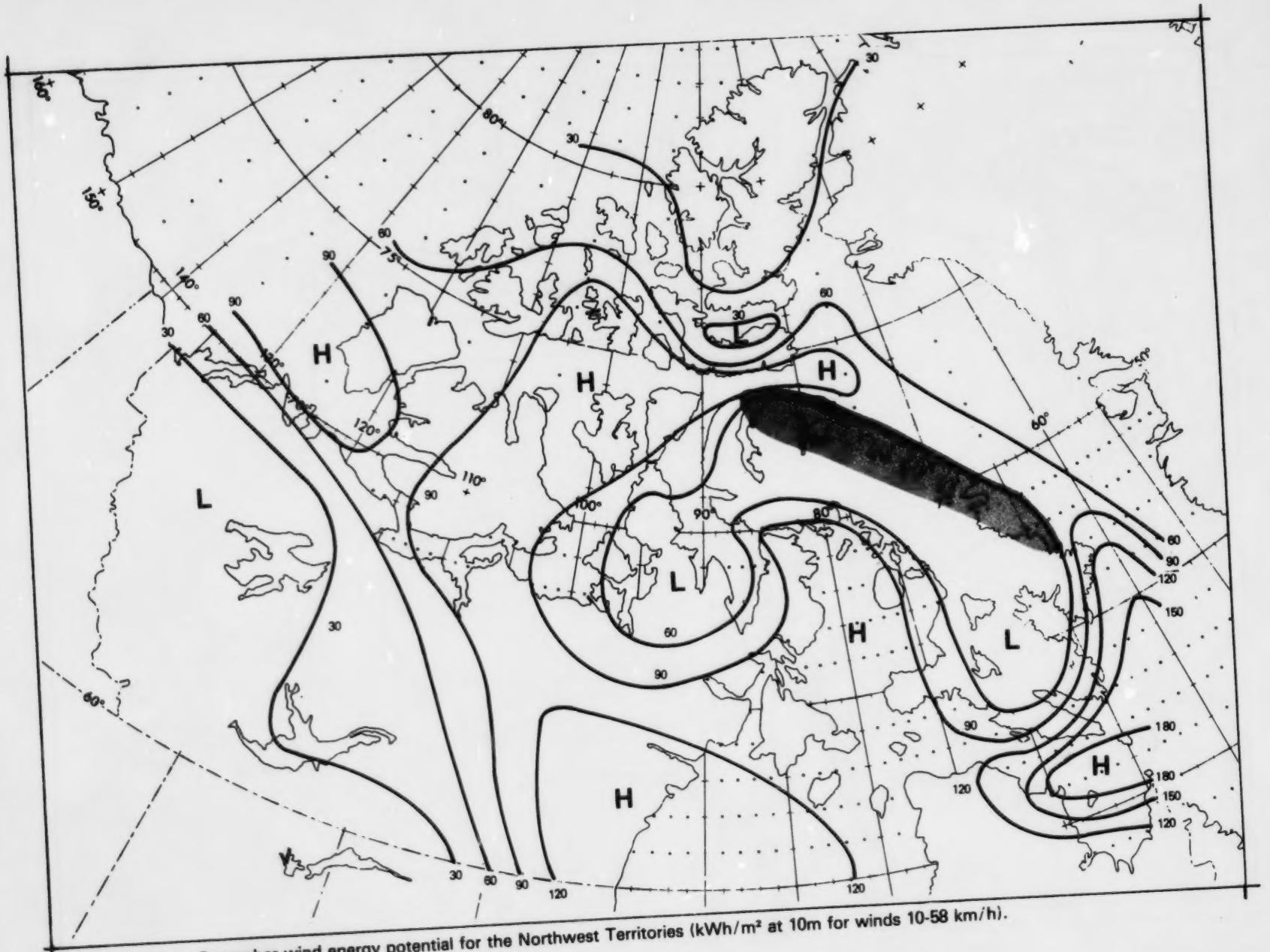


Figure 17. Mean December wind energy potential for the Northwest Territories (kWh/m² at 10m for winds 10-58 km/h).

4.5 WIND-ENERGY POTENTIAL ZONES IN THE NORTHWEST TERRITORIES

The Northwest Territories can be divided into four broad zones on the basis of wind-energy potential (Figure 18). Although the zone limits as suggested here are broad and arbitrary, the underlying assumption is that 600 kWh/m²/yr represents a significant portion of the annual energy requirement of a dwelling or small business. (A machine with a 4 m [diameter] blade and assumed efficiency of 50% would generate about 3700 kWh/yr in an area with wind-energy potential of 600 kWh/m²/yr.)

4.5.1 Poor Potential (< 600 kWh/m²/yr)

Most of the western Northwest Territories, with the exception of the coastal area along the Beaufort Sea and the shore of Great Slave lake, fall into this category. Wind speeds are too low to produce significant amounts of energy. Specialized WECS applications may be feasible for very low power operations, such as automated weather stations and low power radio beacons, especially if augmented with solar power. Isolated sites on higher ground and in valleys may be found which have marginal conditions. In general, however, a suitable site for wind-energy applications may be difficult to find.

4.5.2 Marginal Potential (600-900 kWh/m²/yr)

This zone covers a narrow band from the Arctic Coast bordering Queen Maud Gulf southeastward to east of the Great Bear and Great Slave Lakes. An area along the Arctic Coast around Shepherds Bay appears to fall into this zone also as do the outer islands from northern Banks to Axel Heiberg Islands. Perhaps the most significant area in this zone is the north shore of Great Slave Lake and possibly some spots along the southeast shore.

In this zone, careful siting would be most critical. Seasonal and year-to-year variations would be significant factors in the success or failure of WECS installation.

4.5.3 Good and Very Good Potential (> 900 kWh/m²/yr)

This zone covers the Keewatin, Hudson Strait, the central Queen Elizabeth Islands, and most of the Banks and Victoria Islands, and likely the Beaufort Sea.

In this zone a suitable site should be easy to find. However, there are sheltered areas that are unsuited to WEC applications. Careful site selection can yield high dividends in the economy of operation.

4.5.4 Variable Potential

The term "variable" in this context refers to variability from place to place. This zone covers eastern Baffin Island, and likely much of eastern Ellesmere Island. The place-to-place variability is related to the sharp topographical features. Communities are generally located in sheltered spots where potential is low. In many instances, however, nearby headlands likely have good potential.

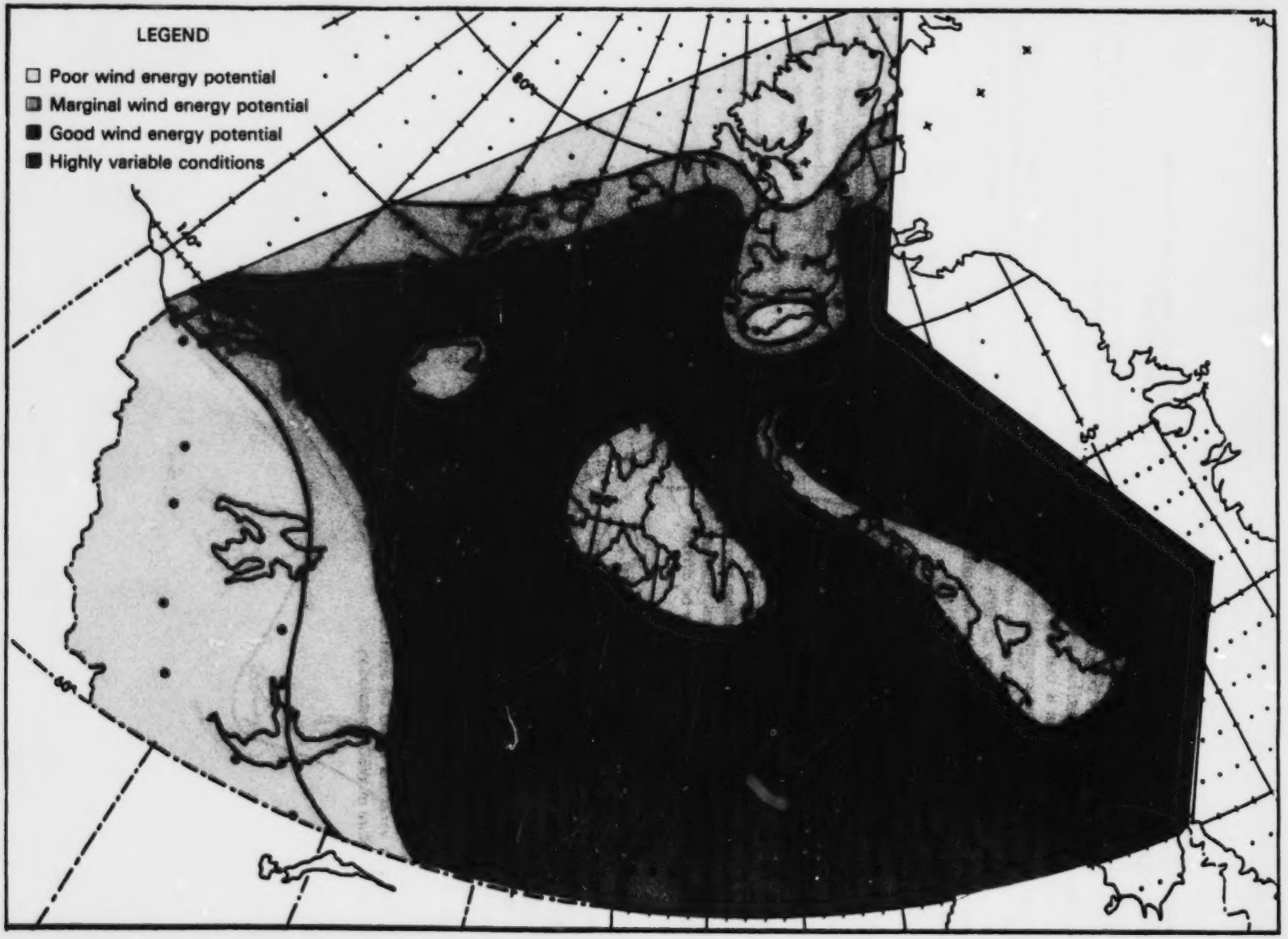


Figure 18. Wind energy potential zones in the Northwest Territories (explanation of symbols in text).

5. Site-Specific Data for Selected Stations in the Northwest Territories

5.1 INTRODUCTION

Site-specific data, generated especially for this report, are presented in this chapter. The data are in graphs (Figures 20 to 95) and tables (Table 4, Appendix). The graphs are intended for use in the design of a wind-energy system for a specific location. The tables are useful in evaluating year-to-year variations.

5.2 DATA BASE AND METHODS

5.2.1 Data Base

The data base used to generate the site-specific graphs and tables consisted essentially of two kinds:

(a) Hourly meteorological observations of 10 years duration (generally 1967-76, Figures 20 to 79).
(b) Meteorological observations with a frequency of less than 24 per day. In some cases the observations were at three-hour intervals, in others a number of overnight observations were routinely missing (Figures 80 to 95).

The stations chosen were generally those with a good record (i.e., relatively few missing observations). With few exceptions, the stations are located at airports throughout the Northwest Territories. Instrument exposure meets the standards set by the Atmospheric Environment Service; an anemometer is relatively free from obstructions and is mounted at the standard 10 m.

5.2.2 Data Processing

Wind-energy calculations are often based on approximations of the energy equation discussed in Section 2.2.1. The calculations forming the basis for the wind-energy climatology presented in Chapter 4 are a case in point. For the site-specific data presented in this chapter, a more rigorous solution of the energy equation was performed; 8766 records of wind (speed and direction), temperature, and atmospheric pressure were processed for each station for each of the 10 years of records. More than 1.6 million records were analysed using the Amdahl computer at the University of Alberta.

The form of the energy equation used to calculate the wind power is:

$$\frac{P}{A} = \frac{0.5926}{2 \times 3.6^2} \rho V^3 \quad \ldots\ldots(5)$$

where P/A is the maximum deliverable wind-stream power per unit stream area, and has the units of W/m². The wind speed, V, is in km/h and the coefficient, 0.5926, is the Betz power factor. The air density, ρ, can be expressed as:

$$\rho = \frac{1.293 \times 273.15}{1.1.325} \times \frac{p}{(T + 273.15)} \quad \ldots\ldots(6)$$

where the constant, 1.293, is the air density at 0°C and 101.325 kPa, p is the air pressure in kPa and T is the temperature in °C. A flow chart outlining the computer program used to solve this form of the energy equation is shown in Figure 101, Appendix. Readers wanting more details of the computer program may contact the Alberta Research Council at the Address given in Section 3.6.1.

5.3 SITE-SPECIFIC GRAPHS AND TABLES

5.3.1 Site-Specific Graphs

Not all the graphs capable of being generated by the computer program are reproduced in this report. Only the four most useful graphs are reproduced for each station (Figures 20 to 95):

1. The Hourly Available Wind Power: This graph shows the diurnal pattern of wind-energy production. Some stations such as Resolute (Figure 71) show very little diurnal effect. Others such as Hay River (Figure 30) show a very marked increase in available wind energy during the mid and late afternoon, especially during the spring and summer months. The peak afternoon power may be about 2.5 times that available during the night. This fact might be useful at a low wind-energy site such as Hay River to design a system for specific low energy applications for afternoon use.
2. Duration and Frequency of Winds ≤ 15 km/h: This graph is useful in designing storage systems. Fifteen km/h was chosen because this is the approximate cut-in speed of many WECS. These graphs indicate that at Resolute (Figure 74), for instance, there was one period in the 10 years when the wind was continuously less than or equal to 15 km/h for a period of 220 hours. At Inuvik (Figure 34), on the other hand, there was one such period which lasted 540 hours. At Resolute there are, on the average, 10 periods per year when the wind is less than or equal to 15 km/h continuously for about 43 hours. At Inuvik, these periods last about 90 hours.
3. The Energy Rose: This graph is useful in the actual siting of a system and shows the direction from the installation which must be kept free of obstructions. At Baker Lake (Figure 58), for instance, the only significant energy comes from northwest to north. A glance at the energy roses of the different stations indicates which stations have a good energy potential and those with poor potential. Comparing Baker Lake (Figure 58) and Inuvik (Figure 35) is rather revealing in this regard. The energy roses are all plotted to the same scale, so the total length of all vectors on each graph is a measure of the total available energy.

4. The Wind-Energy Profile for the Year: This graph is often referred to as the power-duration curve. Knowing the cut-in speed, the rated speed, and the furling speed of a particular machine, the energy available to this machine can be calculated. A schematic of such a calculation is shown in Figure 19.

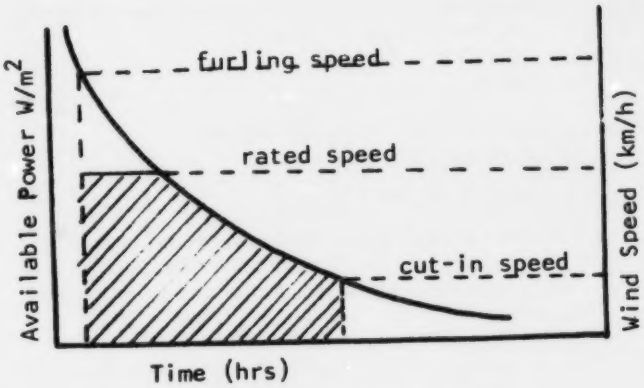


Figure 19. Schematic of a power-duration curve.
In the above figure the area under the curve is a measure of the wind energy available to a specific machine. An efficiency factor must be applied to the calculated energy to obtain the actual energy that the particular device could extract from the wind.

The numbers on the site-specific energy profiles represent the total area, and thus energy, to the left of the ordinate through the respective number. This facilitates the calculation of the total energy represented by area under the curve.

5.3.2 Wind and Wind-Energy Summary Tables (Appendix, Table 4)

5.3.2.1 Discussion of Tables.

The analysis procedure discussed in Section 5.2.2 generates a set of tables for each graph, in addition to tables relating to wind-speed and wind-energy summaries. Some of these data are reproduced in the Appendix (Table 4) of this report, which has an explanation of the tables.

The annual recorded potential wind-energy data are rather significant (Table 4). The important feature is the year-to-year variations in total potential wind energy. At Baker Lake, for example, the year with the highest potential energy (1970) has about three times the energy of the lowest year (1974) of the analysis period. This feature of year-to-year variations shows up at all stations that have good wind-energy potential. These variations may complicate the realization of a satisfactory wind-energy program in the Northwest Territories. Any serious program must take into account that annual potential energy may differ from the long-term average by as much as 50%. Some form of back-up or auxiliary power supply must be available to cover this possibility.

Potential wind energy for one month when compared to the same month in another year may show wide variations (particularly in winter months). A comparison of January 1974 with January 1971 at Baker Lake illustrates this point.

Statements to the effect that annual wind patterns are relatively unchanging and can be predicted with a high degree of confidence have appeared in the literature (Sandwell Beak Research Group, 1979). Whatever merit such statements may have in southern parts of Canada, the data in this report clearly indicate that **such statements do not apply to the Northwest Territories.** Comparable calculations, using the same analysis procedure, for southern Alberta suggest that this phenomenon of year-to-year variations is not unique to the Northwest Territories.

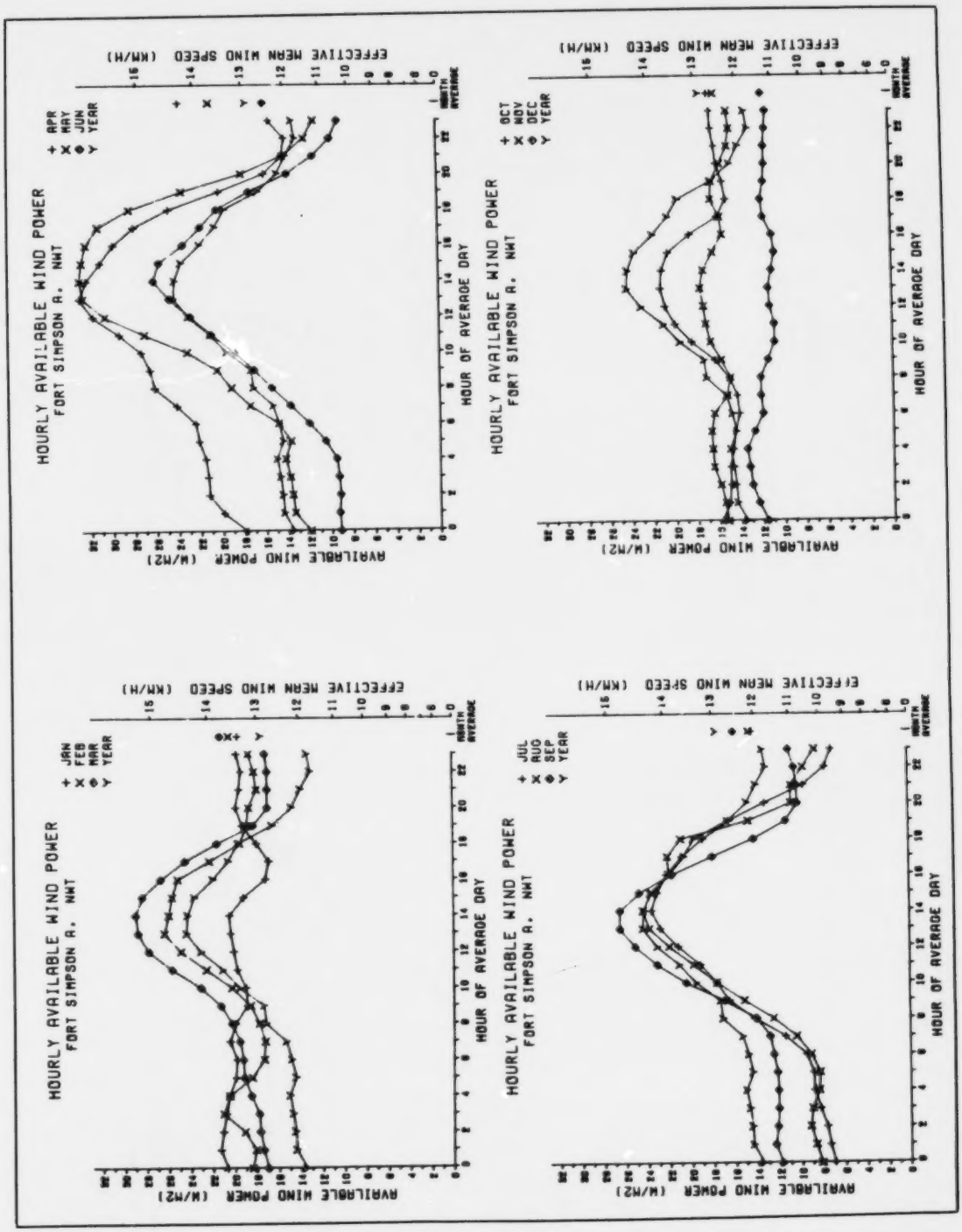


Figure 20. Hourly available wind power, Fort Simpson A, NWT.

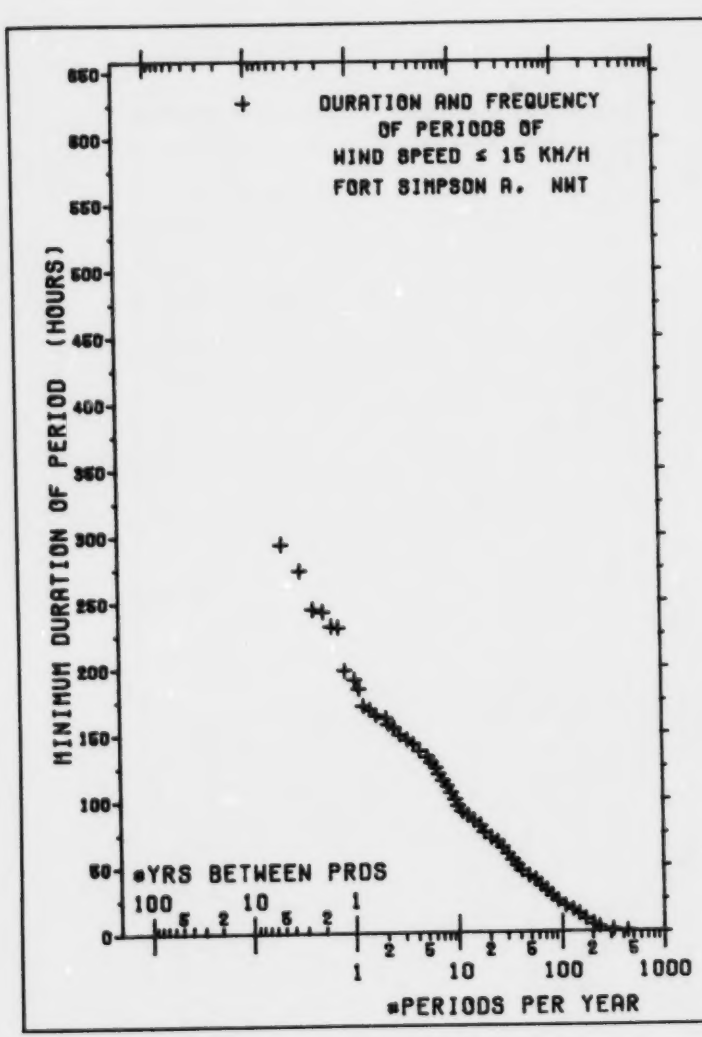


Figure 21. Duration and frequency of winds ≤ 15 km/h for Fort Simpson A, NWT.

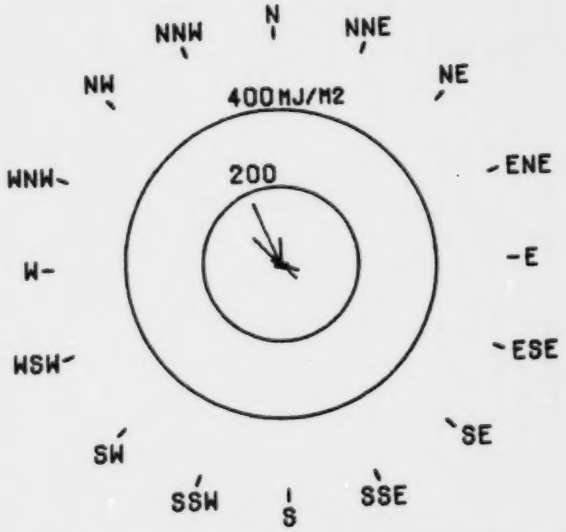


Figure 22. Energy rose for Fort Simpson A, NWT.

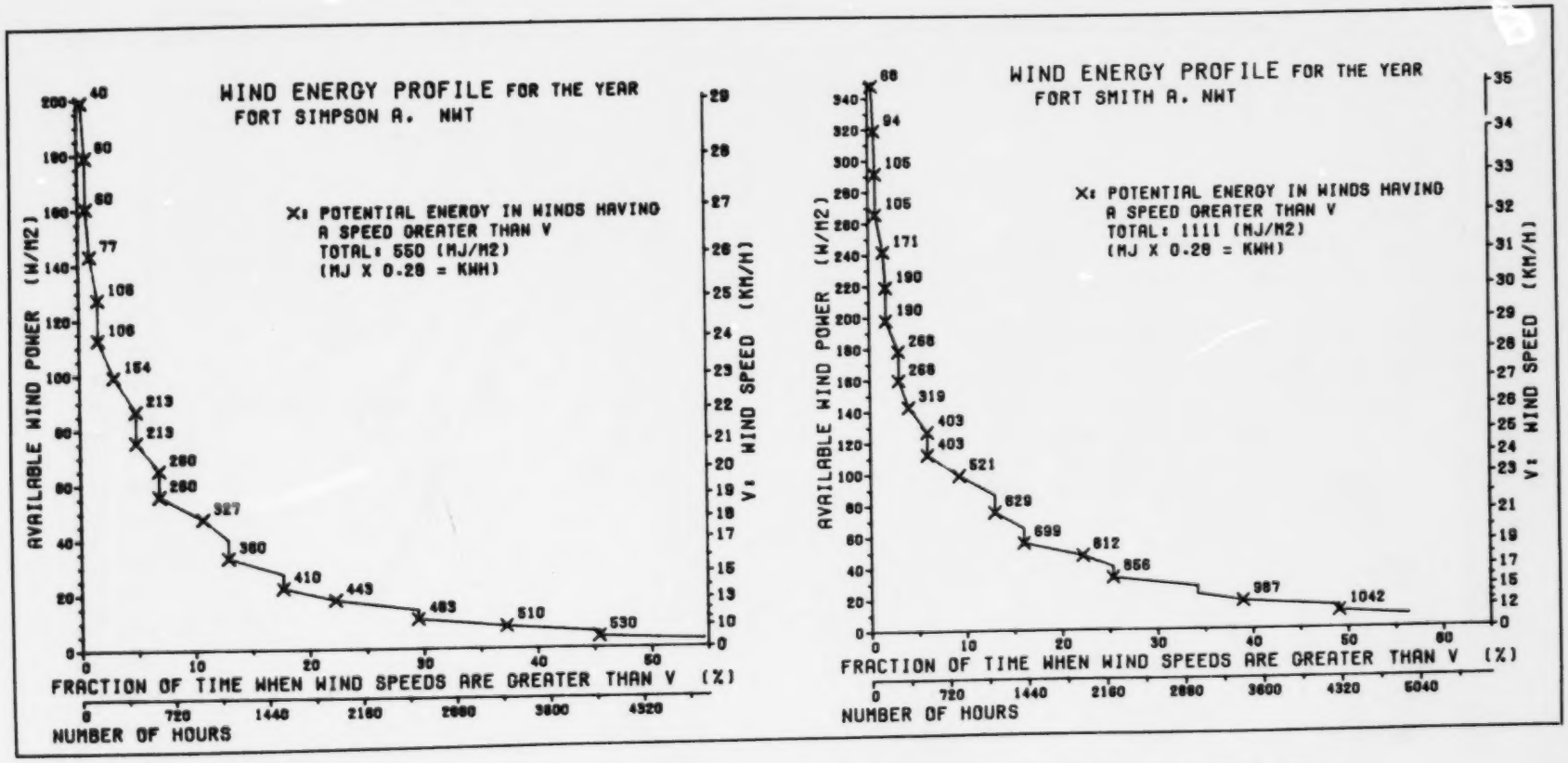


Figure 23. Annual wind-energy profile for Fort Simpson A, NWT.

Figure 24. Annual wind-energy profile for Fort Smith A, NWT.

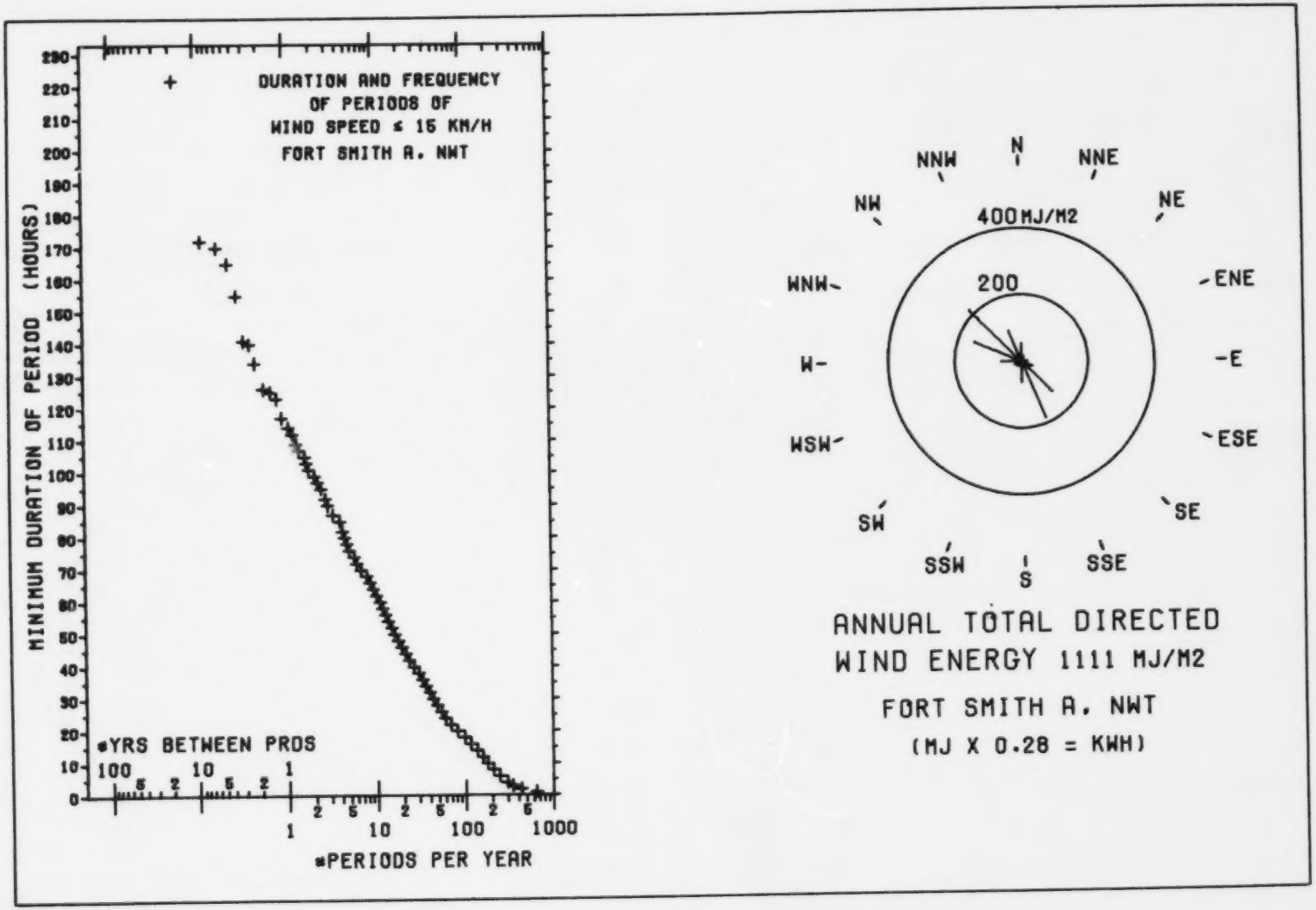


Figure 25. Duration and frequency of winds ≤ 15 km/h for Fort Smith A, NWT.

Figure 26. Energy rose for Fort Smith A, NWT.

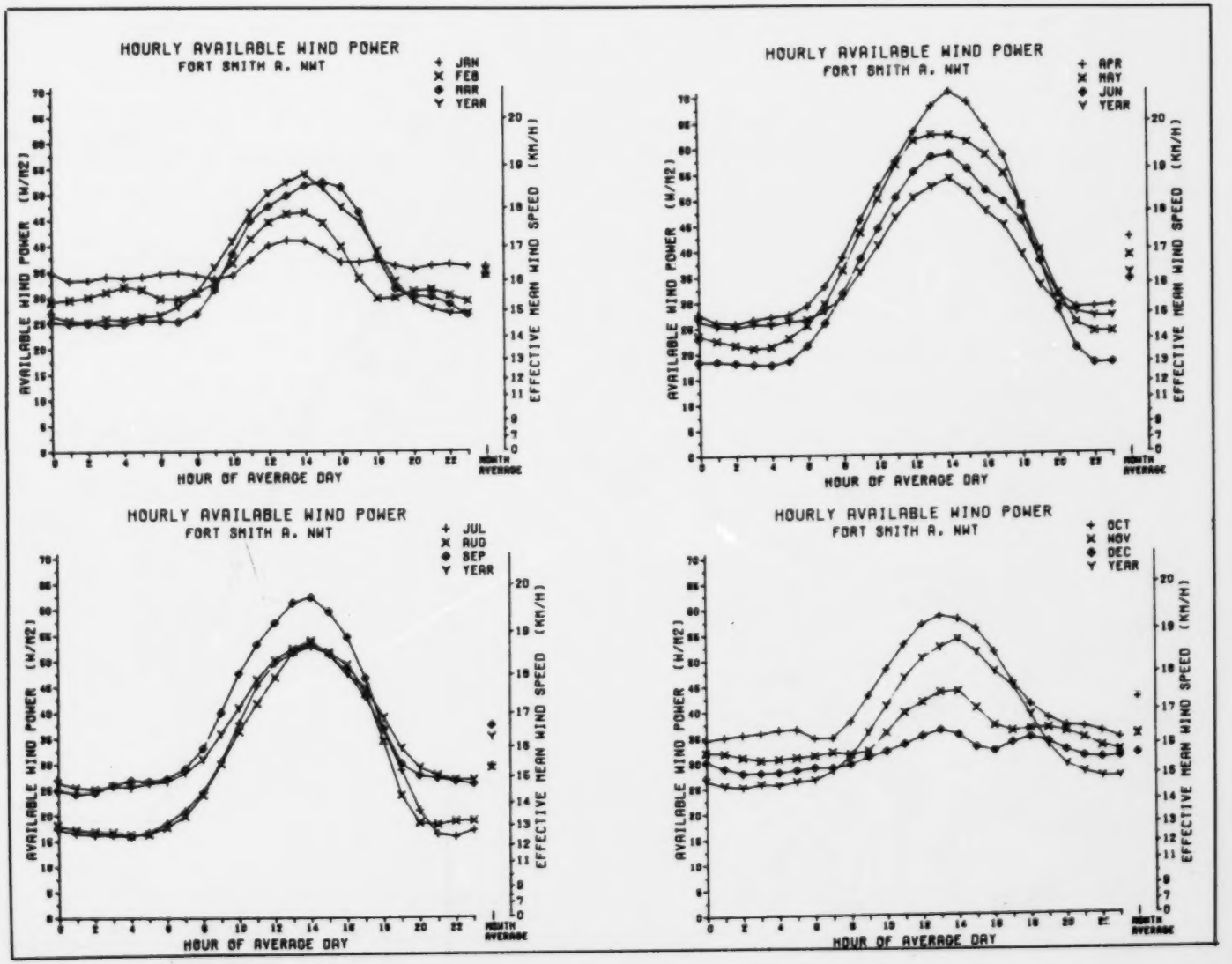


Figure 27. Hourly available wind power, Fort Smith A, NWT.

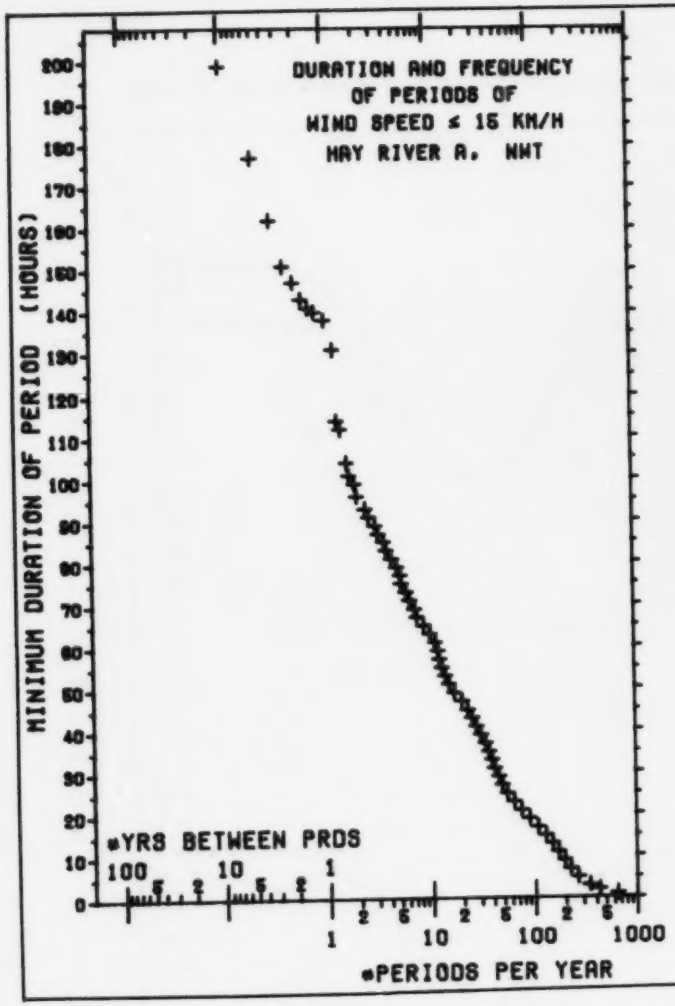


Figure 28. Duration and frequency of winds ≤15 km/h for Hay River A, NWT.

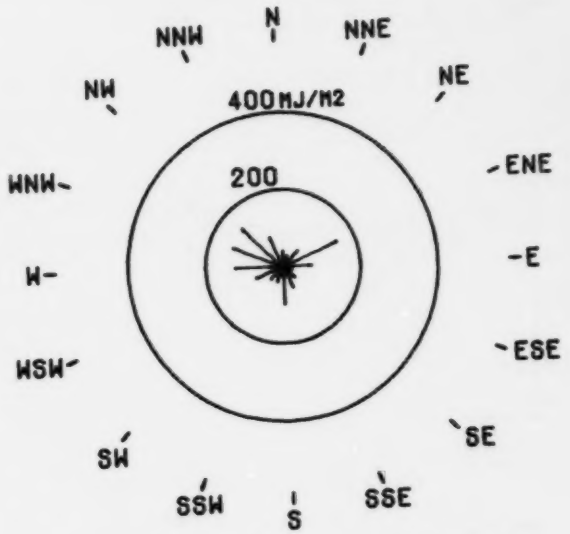


Figure 29. Energy rose for Hay River A, NWT.

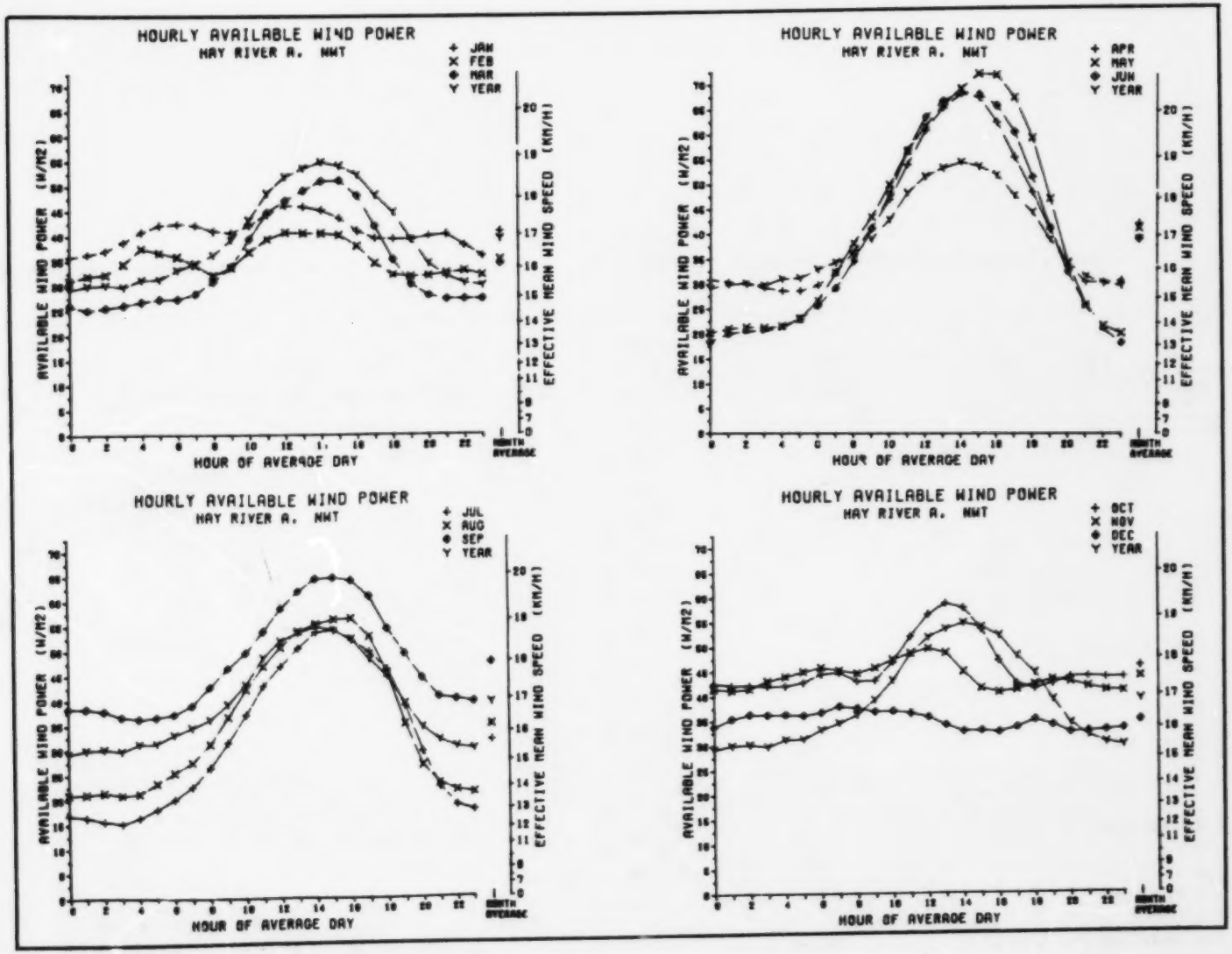


Figure 30. Hourly available wind power, Hay River A, NWT.

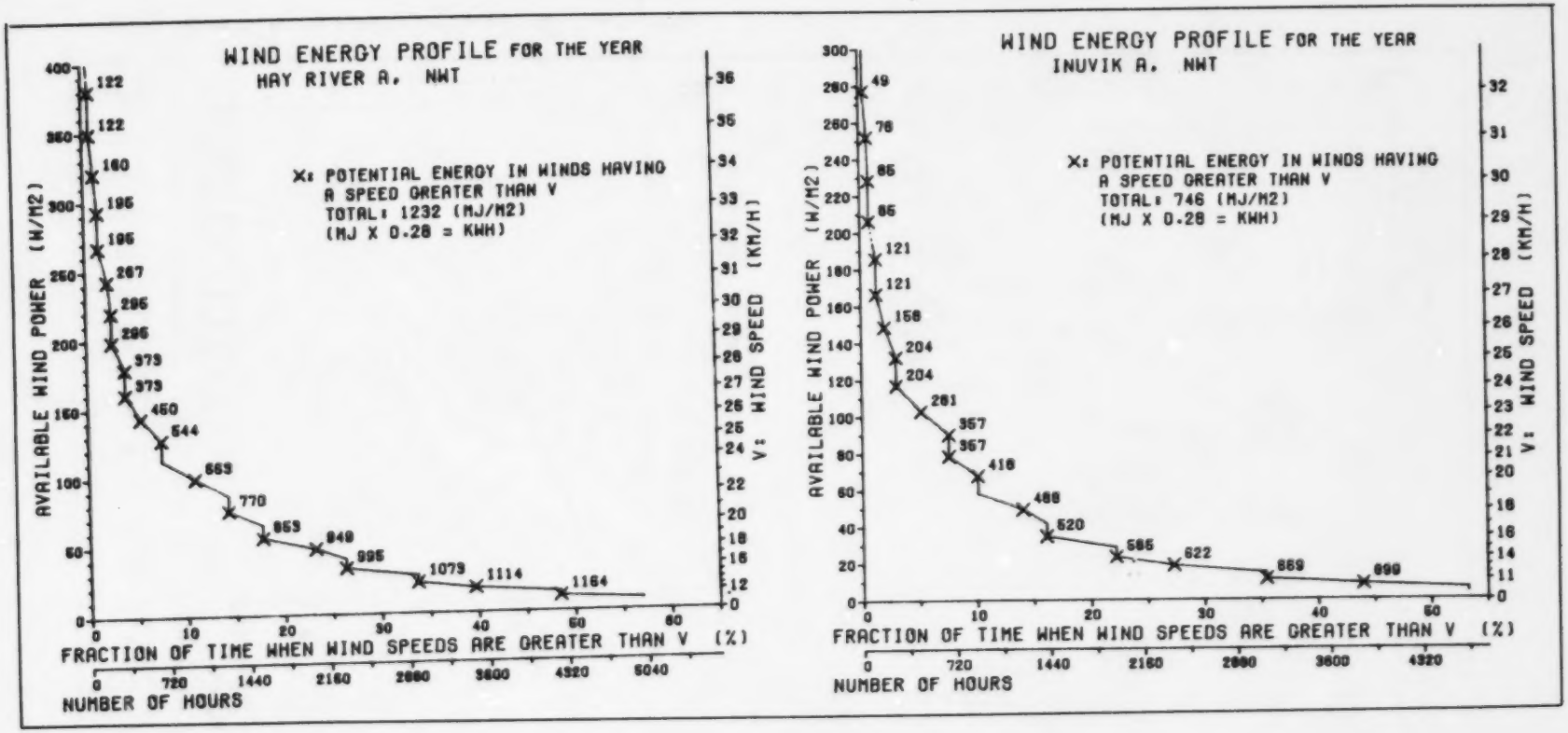


Figure 31. Annual wind-energy profile for Hay River A, NWT.

Figure 32. Annual wind-energy profile for Inuvik A, NWT.

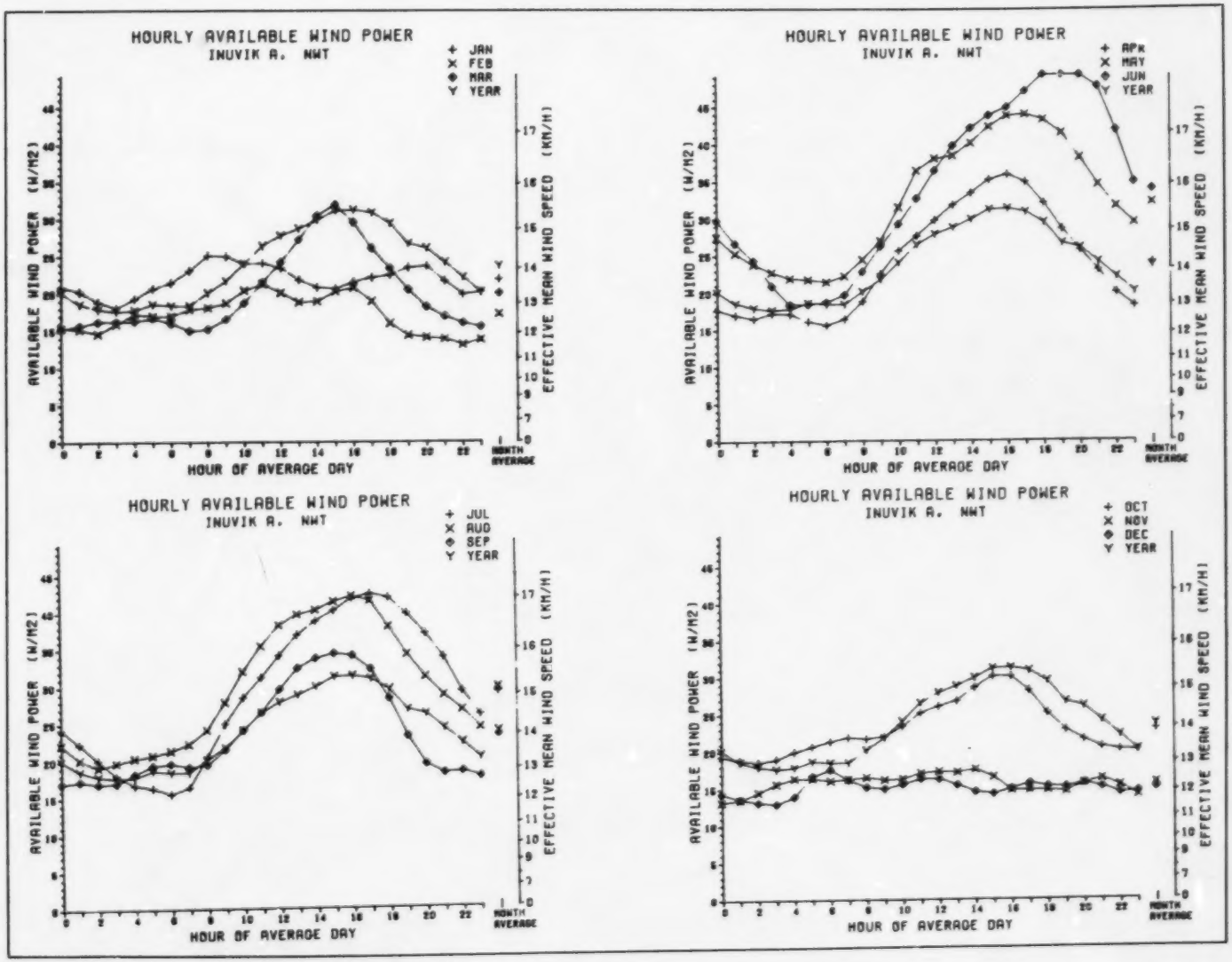


Figure 33. Hourly available wind power, Inuvik A, NWT.

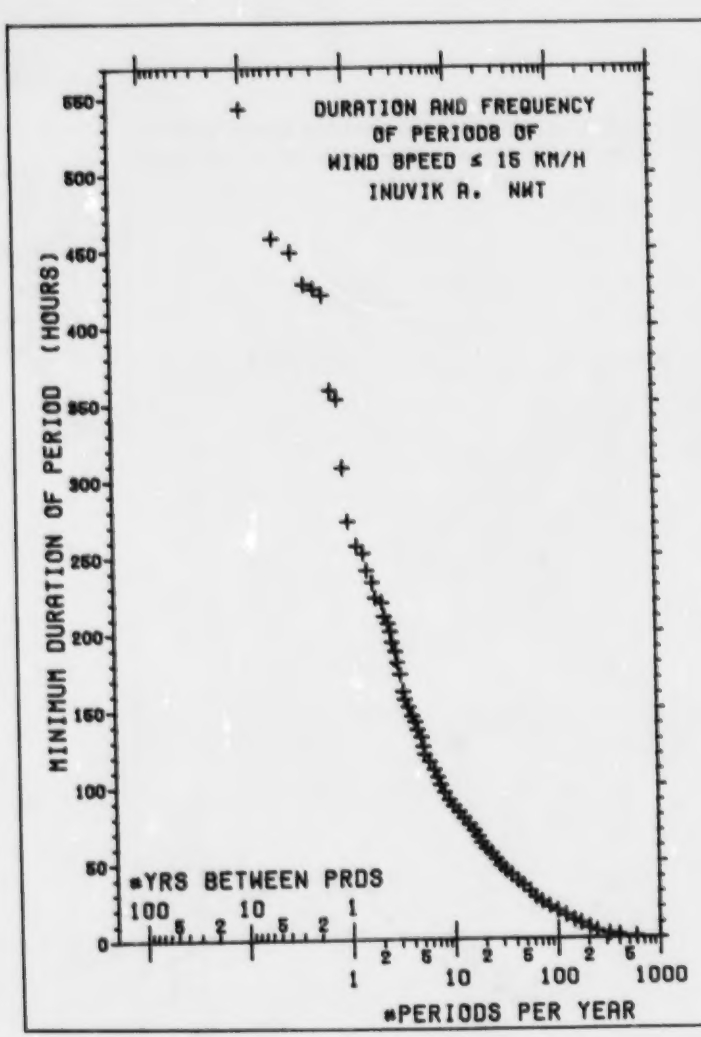


Figure 34. Duration and frequency of winds ≤ 15 km/h for Inuvik A, NWT.

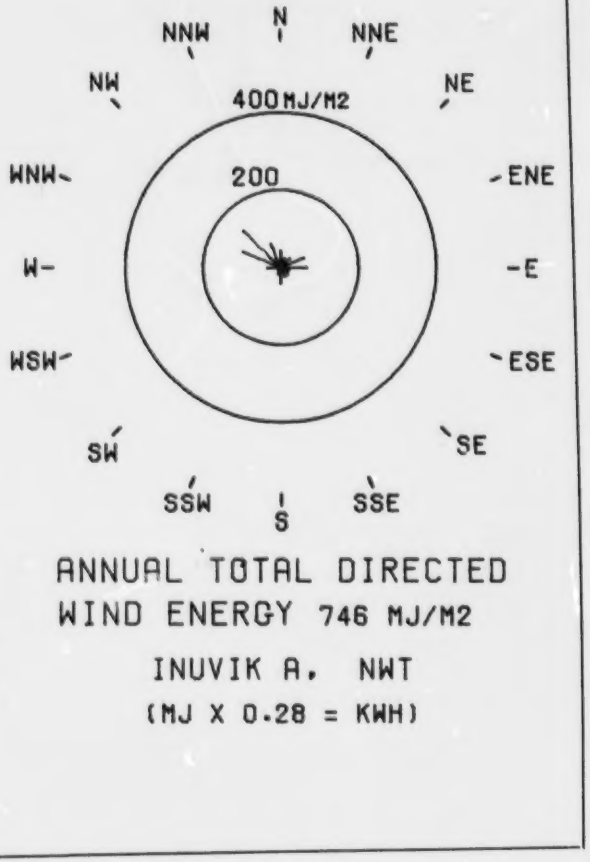


Figure 35. Energy rose for Inuvik A, NWT.

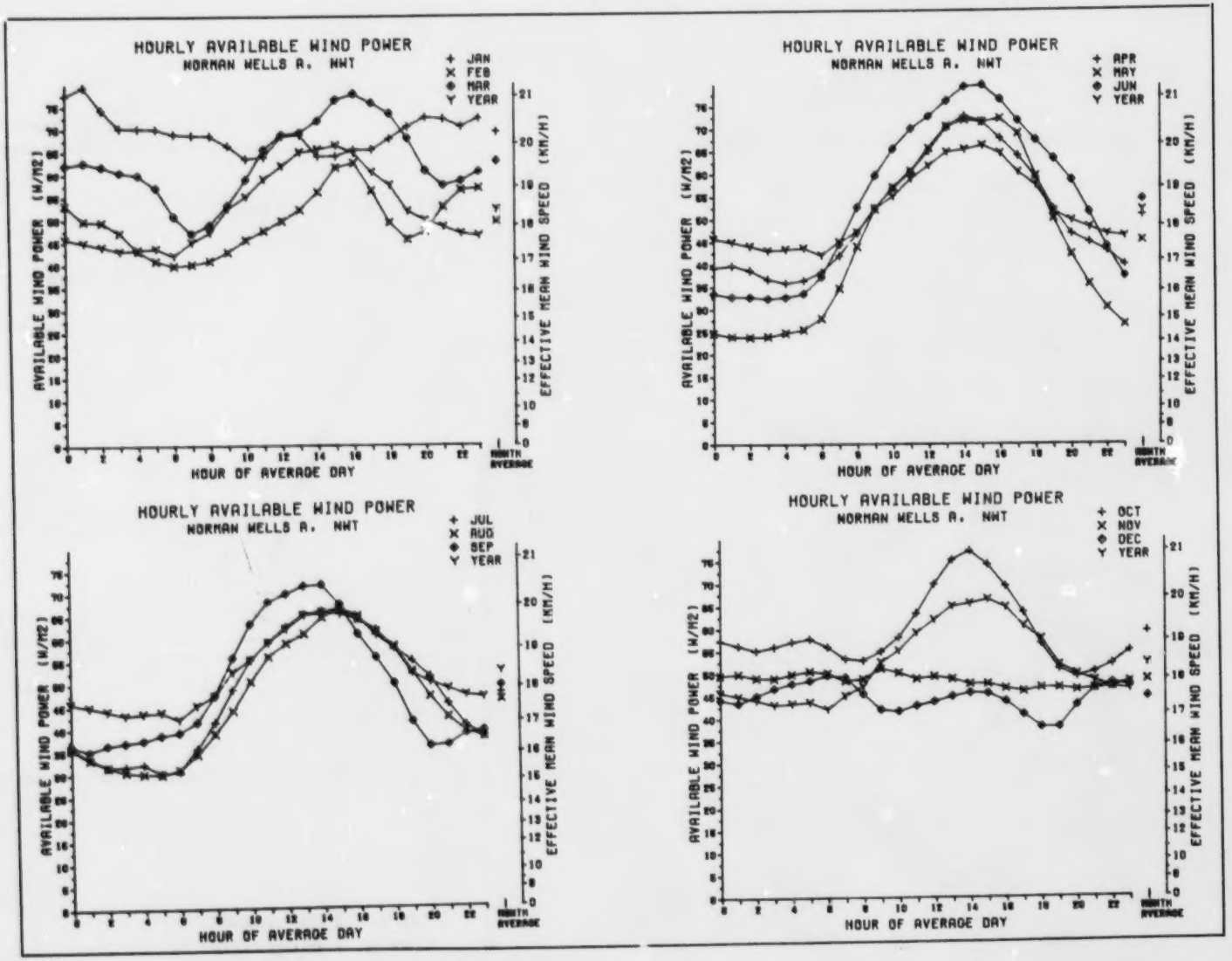


Figure 36. Hourly available wind power, Norman Wells A, NWT.

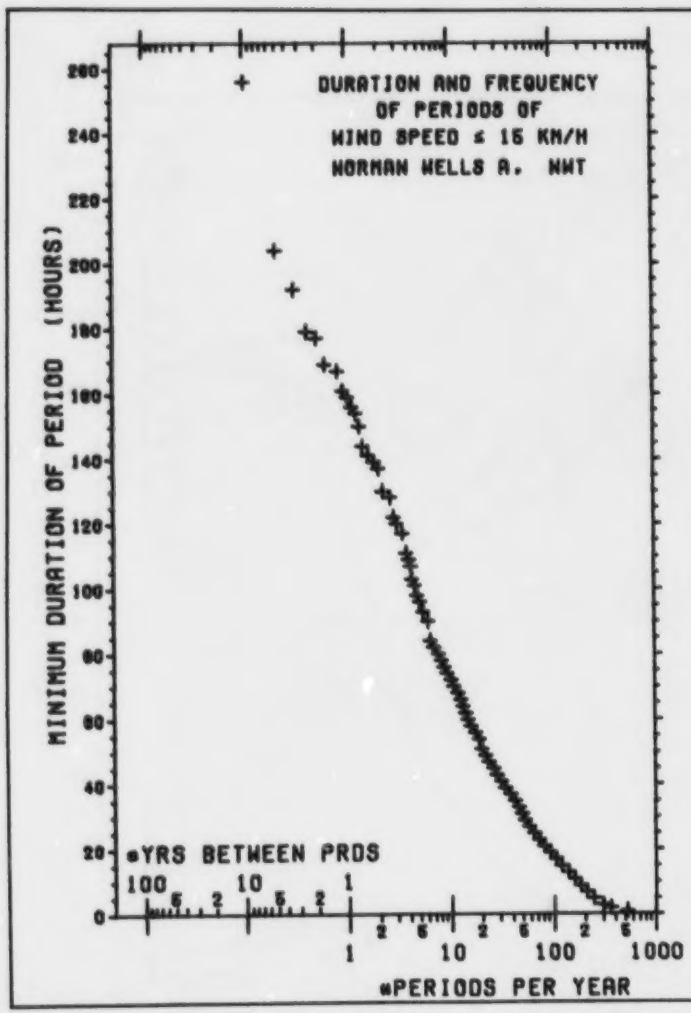
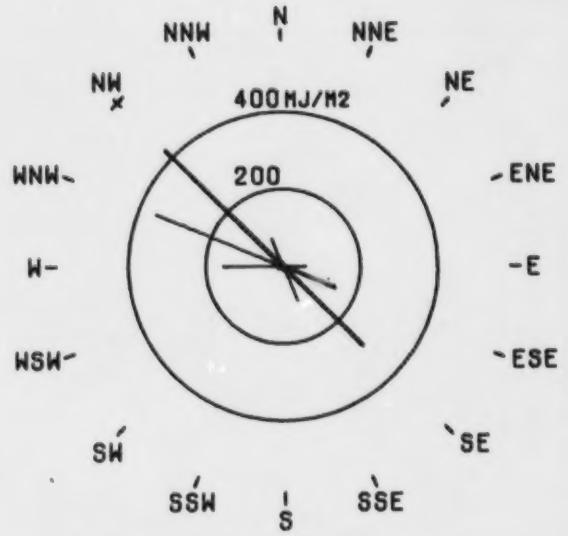


Figure 37. Duration and frequency of winds ≤15 km/h for Norman Wells A, NWT.



ANNUAL TOTAL DIRECTED
WIND ENERGY 1640 MJ/M2
NORMAN WELLS A. NWT
(MJ X 0.28 = KWH)

Figure 38. Energy rose for Norman Wells A, NWT.

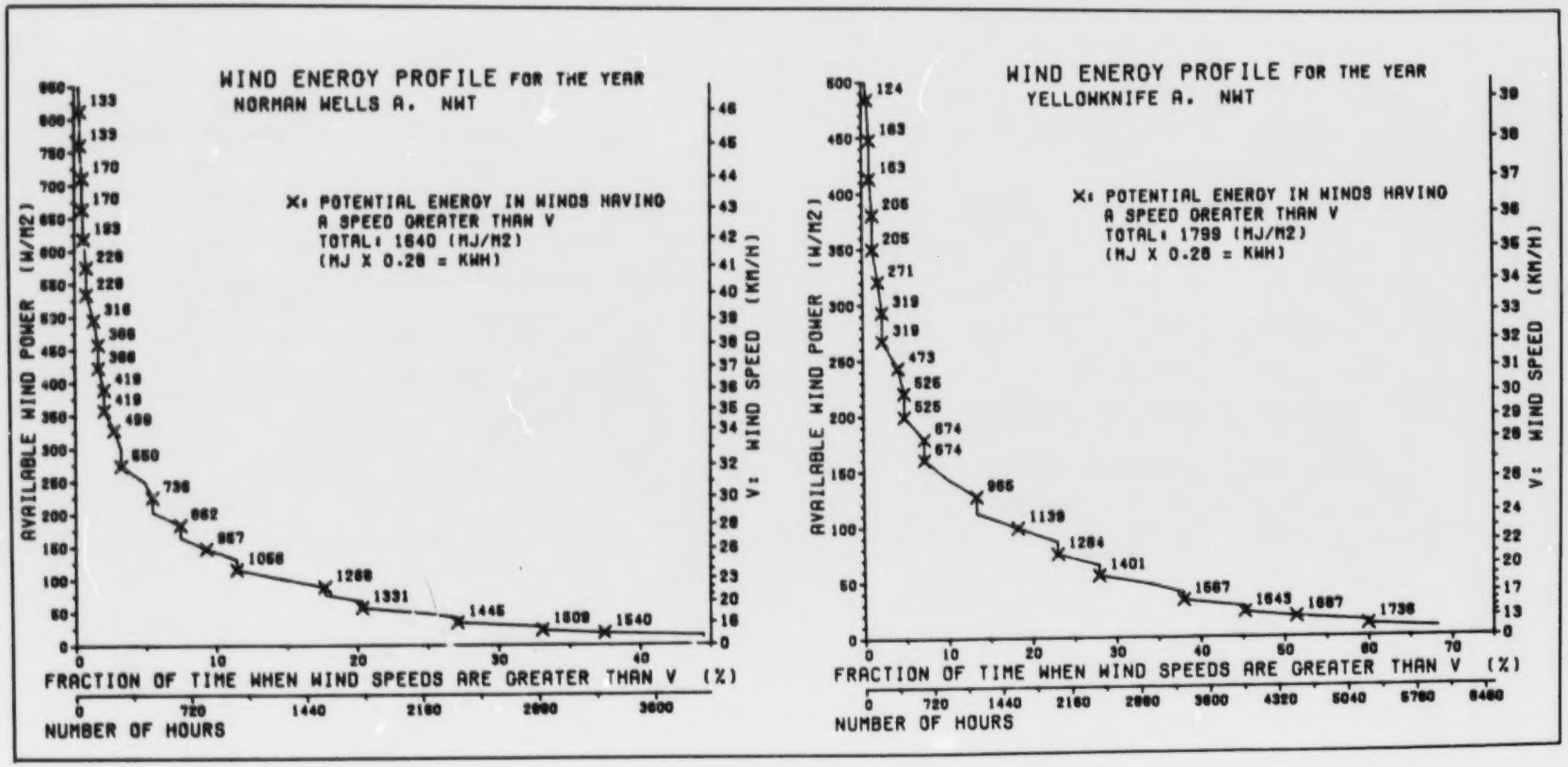

WIND ENERGY PROFILE FOR THE YEAR
NORMAN WELLS A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING A SPEED GREATER THAN V
TOTAL: 1640 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS
WIND ENERGY PROFILE FOR THE YEAR
YELLOWKNIFE A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING A SPEED GREATER THAN V
TOTAL: 1799 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 39. Annual wind-energy profile for Norman Wells A, NWT.

Figure 40. Annual wind-energy profile for Yellowknife A, NWT.

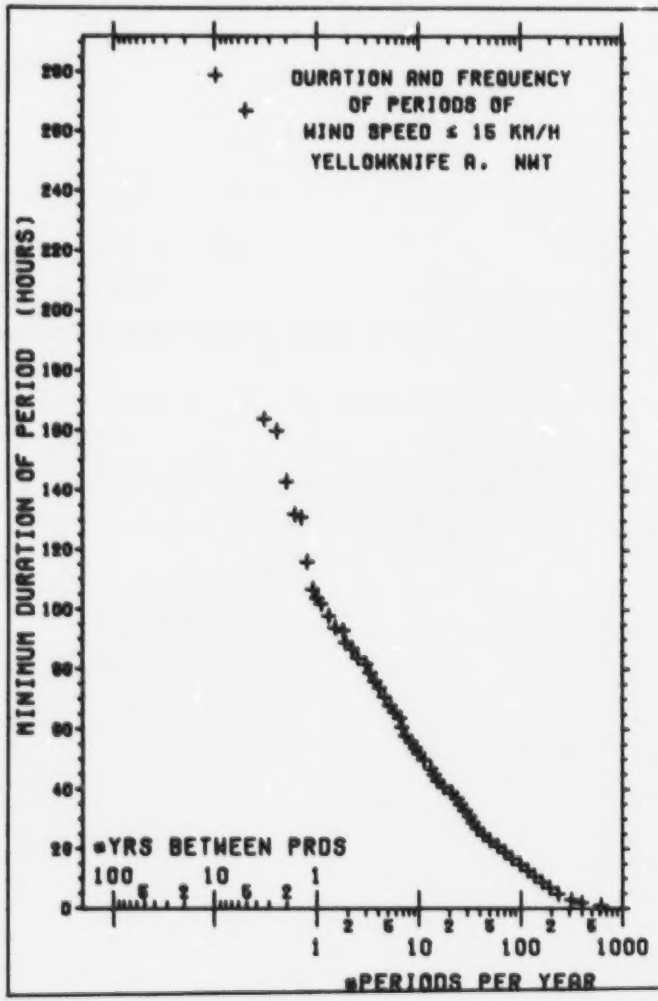
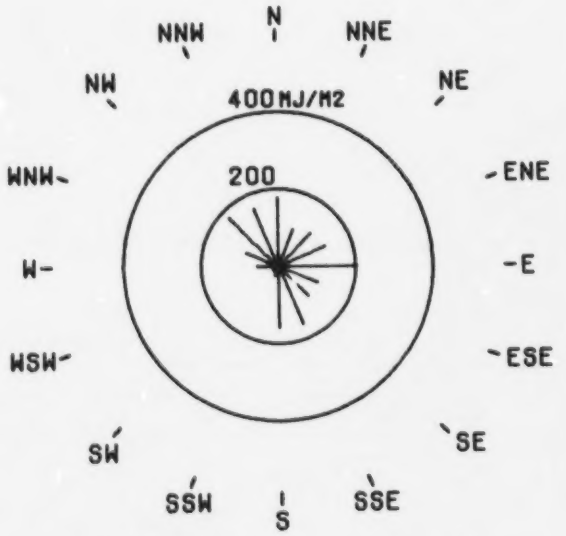


Figure 41. Duration and frequency of winds ≤ 15 km/h for Yellowknife A, NWT.



ANNUAL TOTAL DIRECTED
WIND ENERGY 1799 MJ/M2

YELLOWKNIFE A. NWT

(MJ X 0.28 = KWH)

Figure 42. Energy rose for Yellowknife A, NWT.

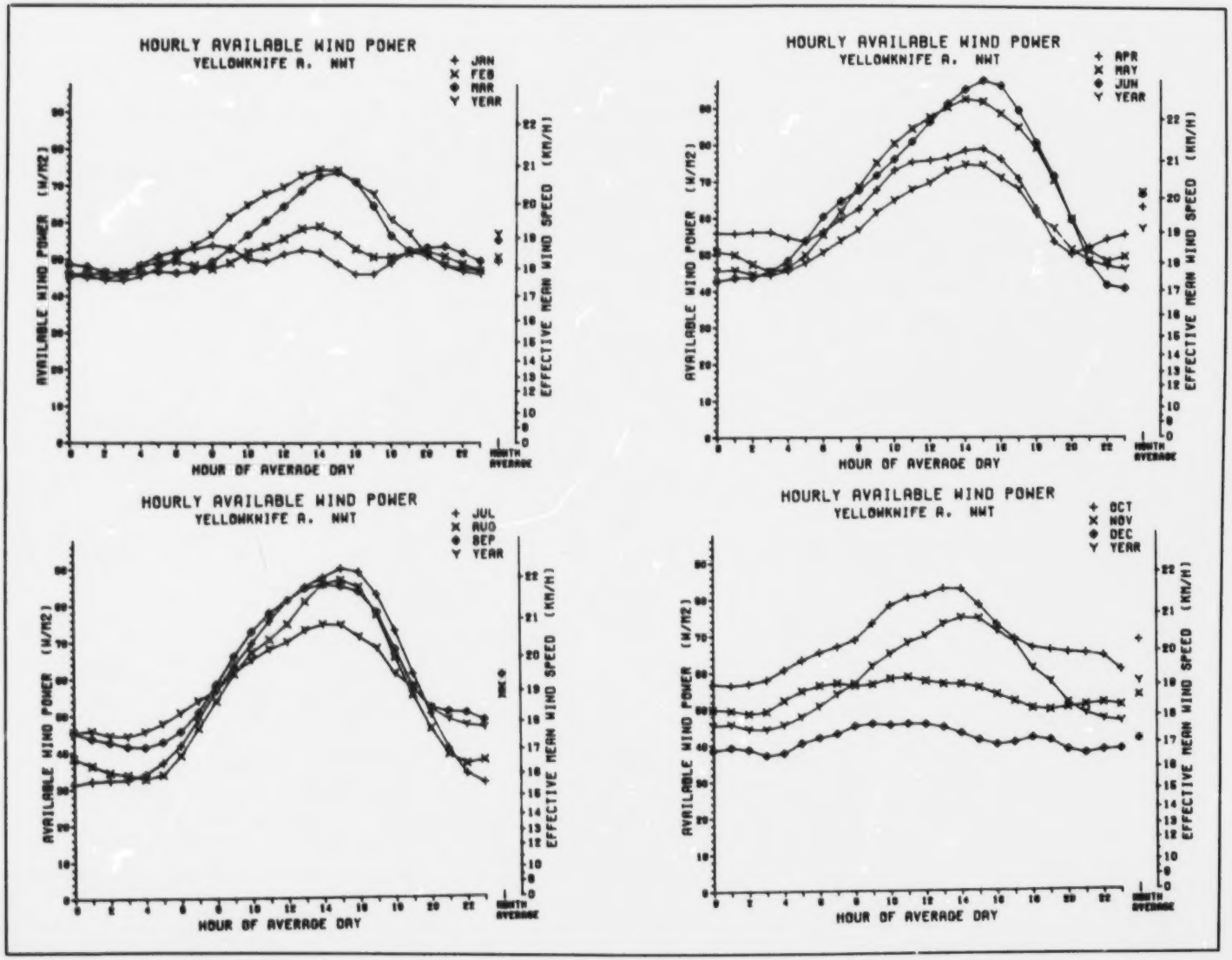


Figure 43. Hourly available wind power, Yellowknife A, NWT.

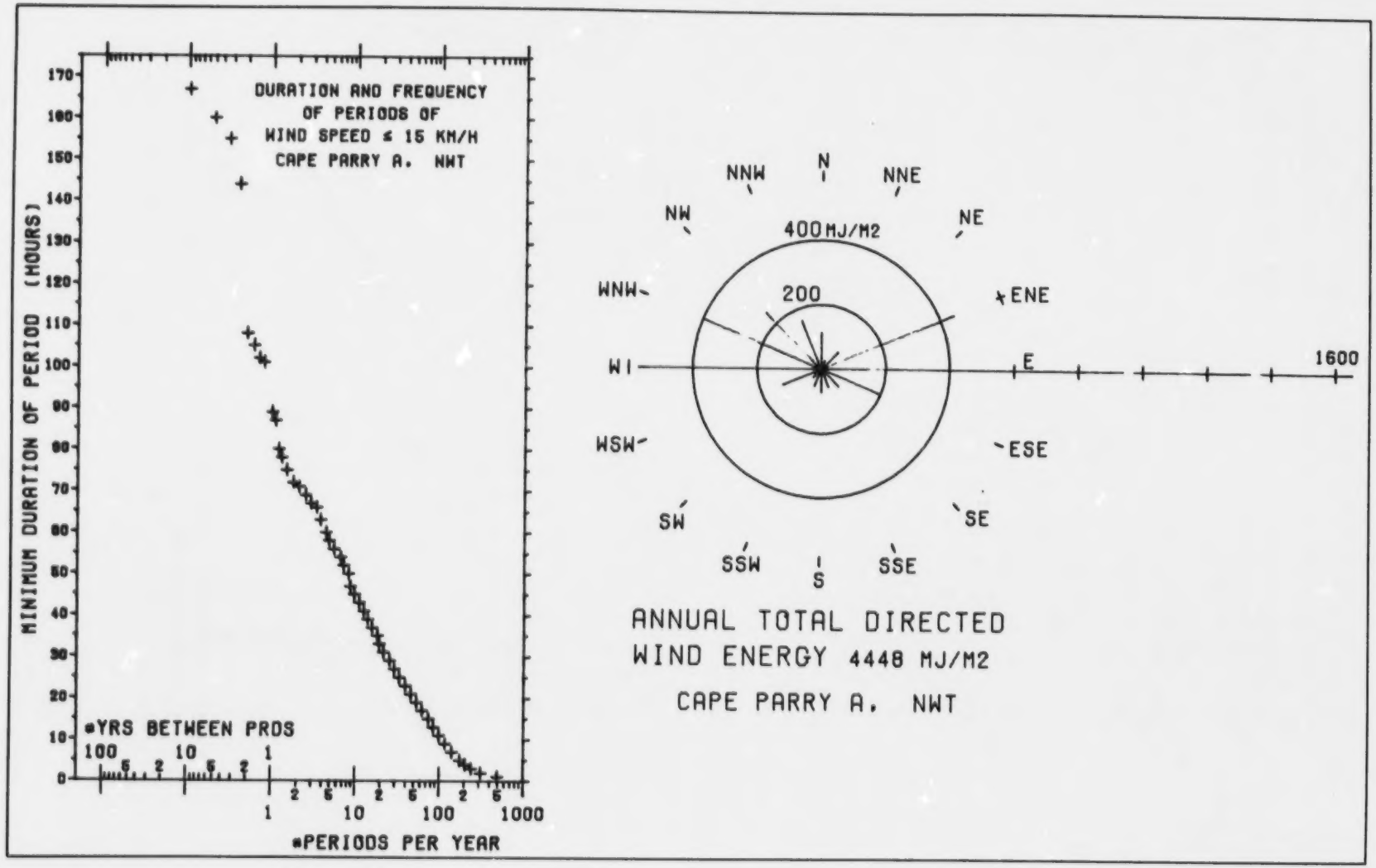


Figure 44. Duration and frequency of winds ≤ 15 km/h for Cape Parry A, NWT.

Figure 45. Energy rose for Cape Parry A, NWT.

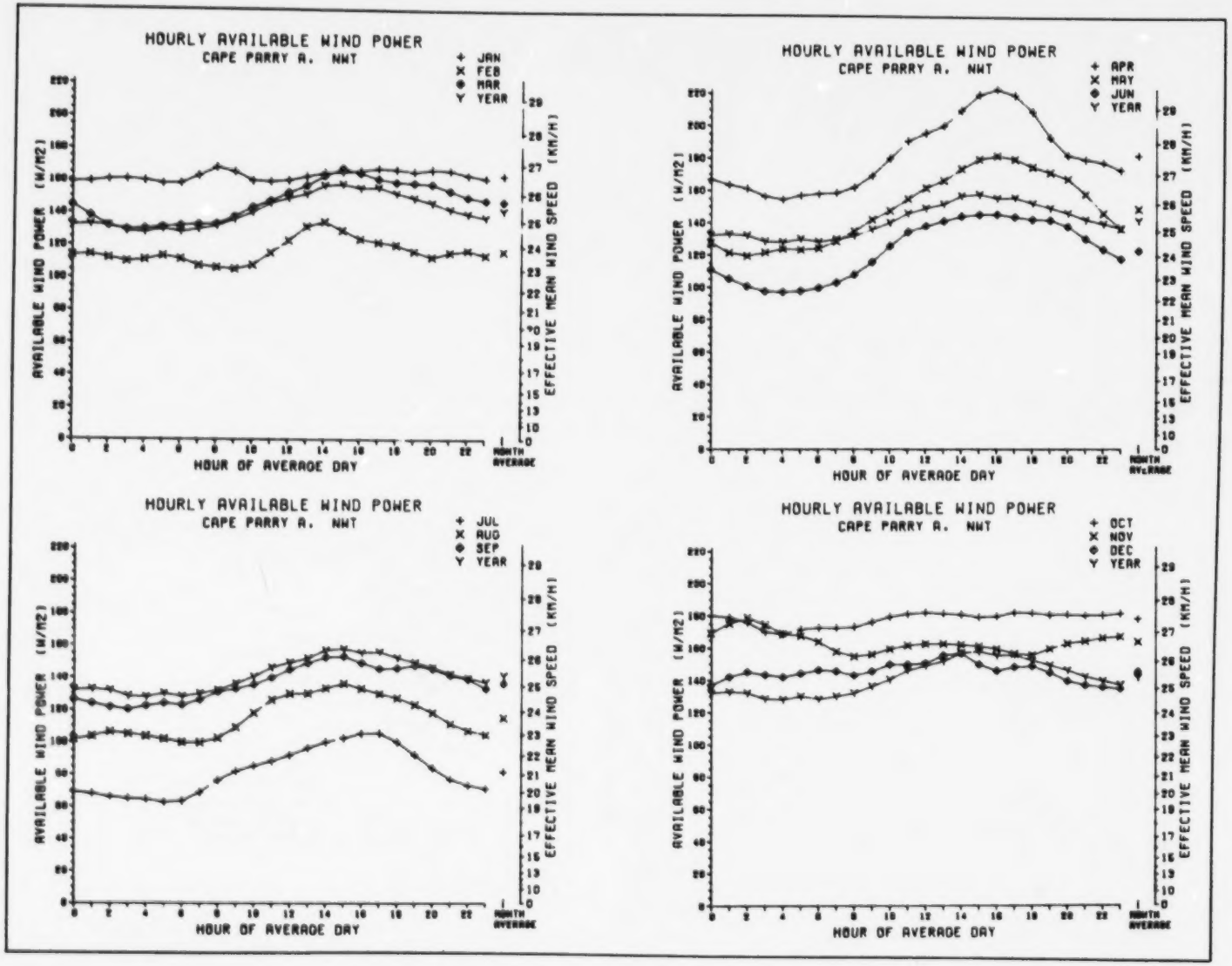


Figure 48. Hourly available wind power, Cape Parry A, NWT.

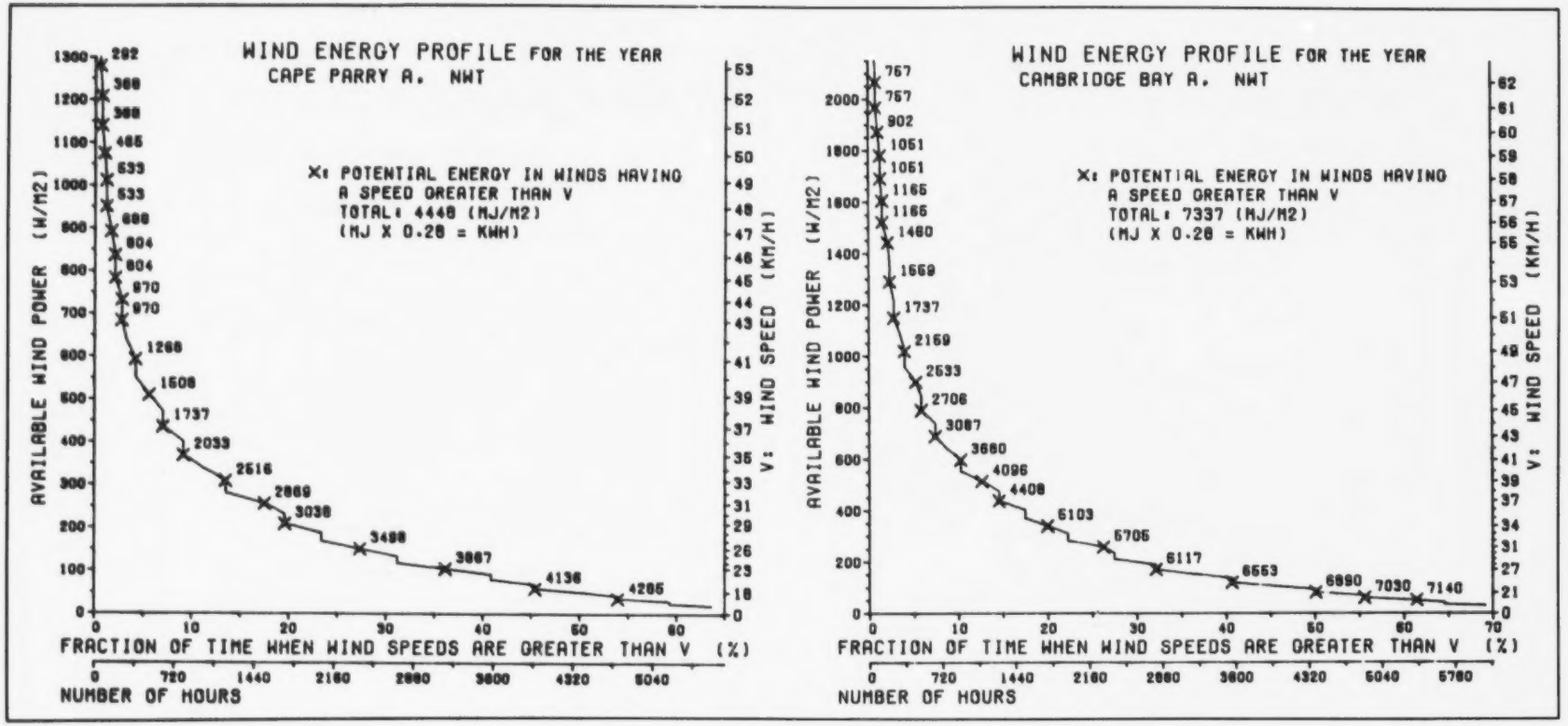

WIND ENERGY PROFILE FOR THE YEAR
CAPE PARRY A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING A SPEED GREATER THAN V
TOTAL: 4448 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS
WIND ENERGY PROFILE FOR THE YEAR
CAMBRIDGE BAY A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING A SPEED GREATER THAN V
TOTAL: 7337 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 47. Annual wind-energy profile for Cape Parry A, NWT.

Figure 48. Annual wind-energy profile for Cambridge Bay A, NWT.

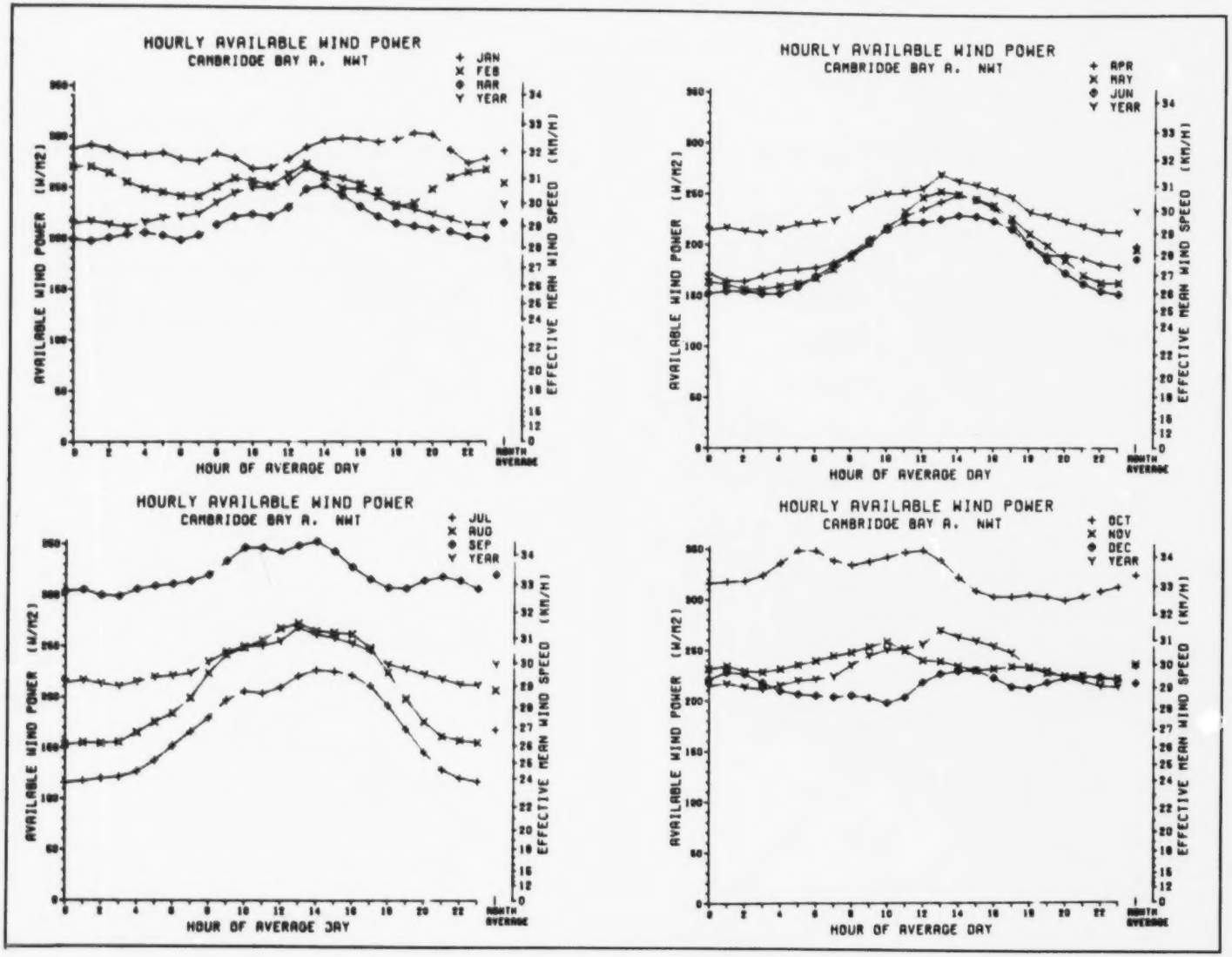


Figure 49. Hourly available wind power, Cambridge Bay A, NWT.

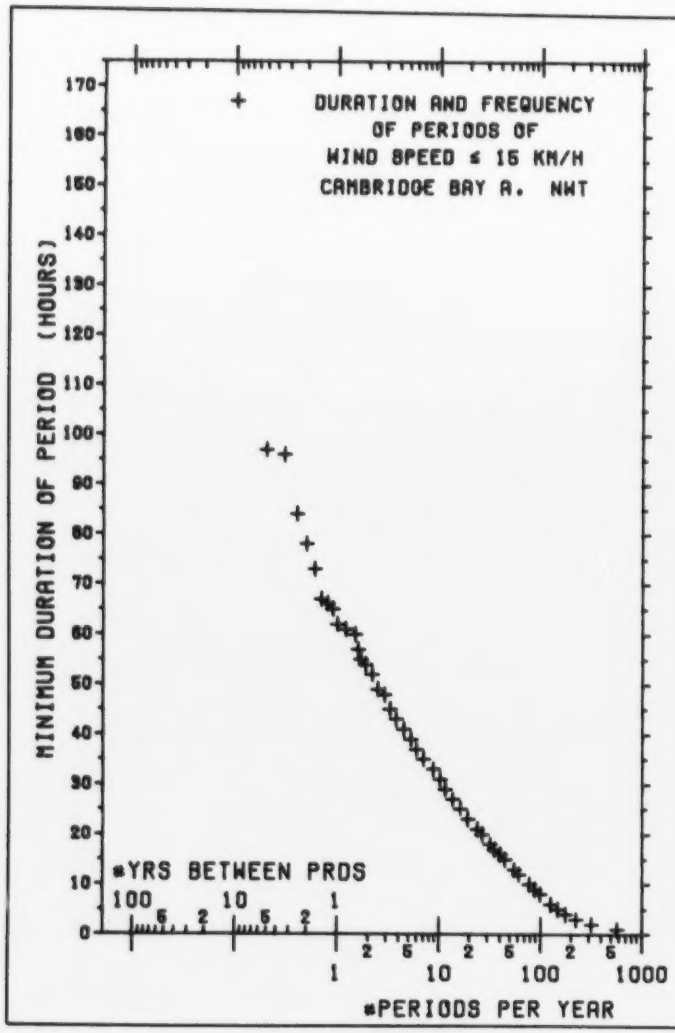


Figure 50. Duration and frequency of winds ⩽15 km/h, Cambridge Bay A, NWT.

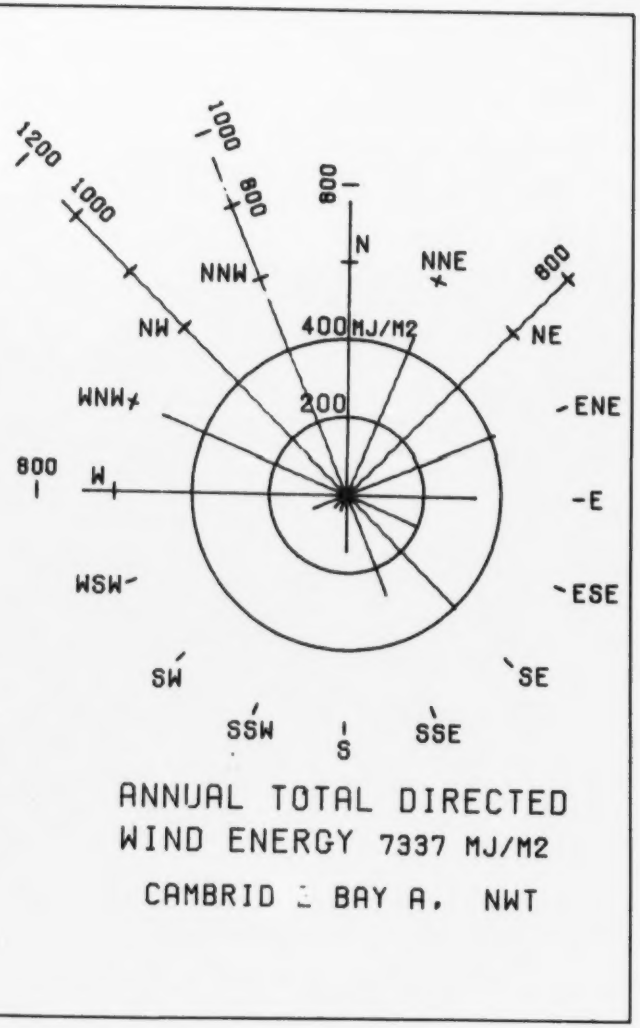


Figure 51. Energy rose, Cambridge Bay A, NWT.

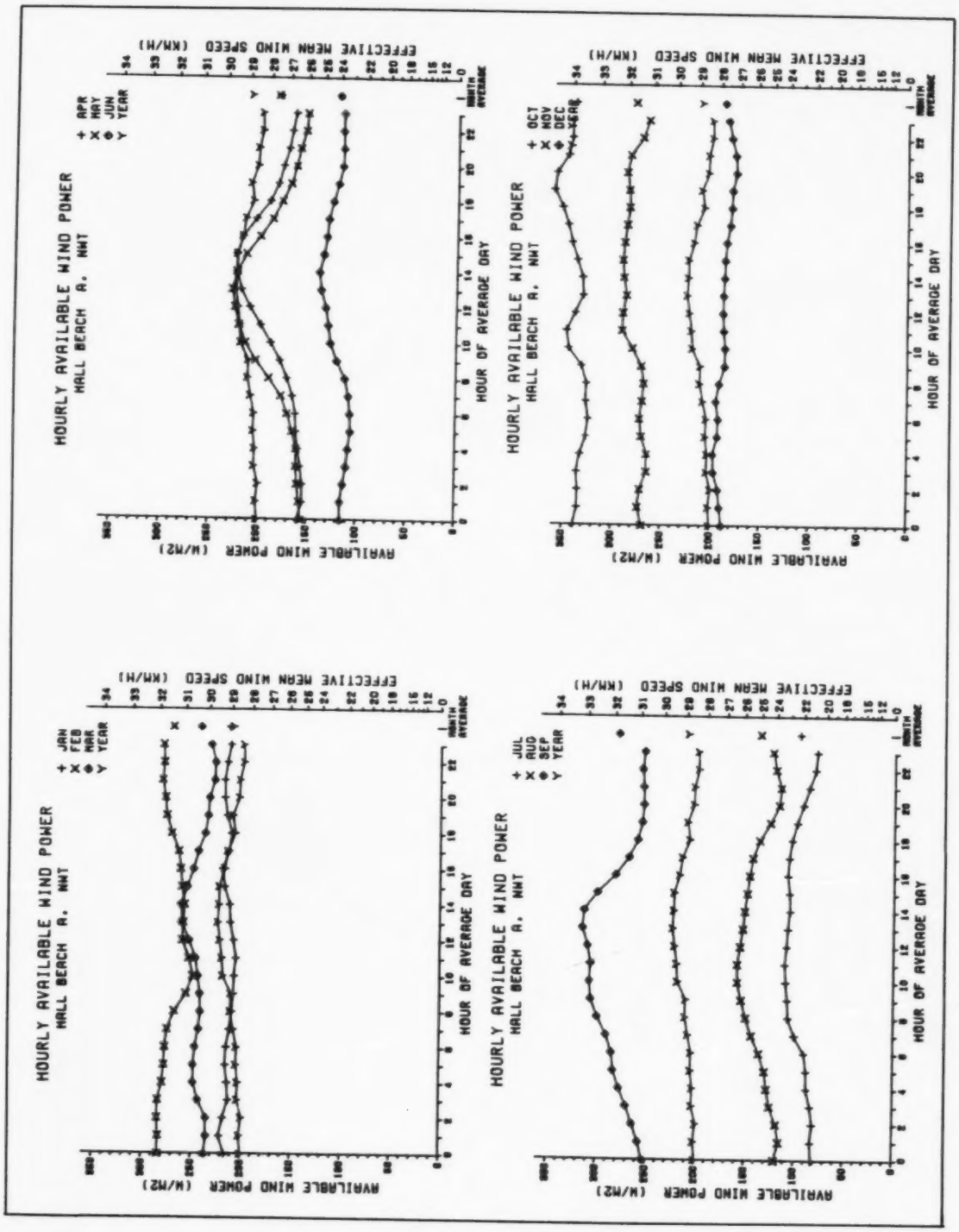


Figure 52. Hourly available wind power, Hall Beach A, NWT.

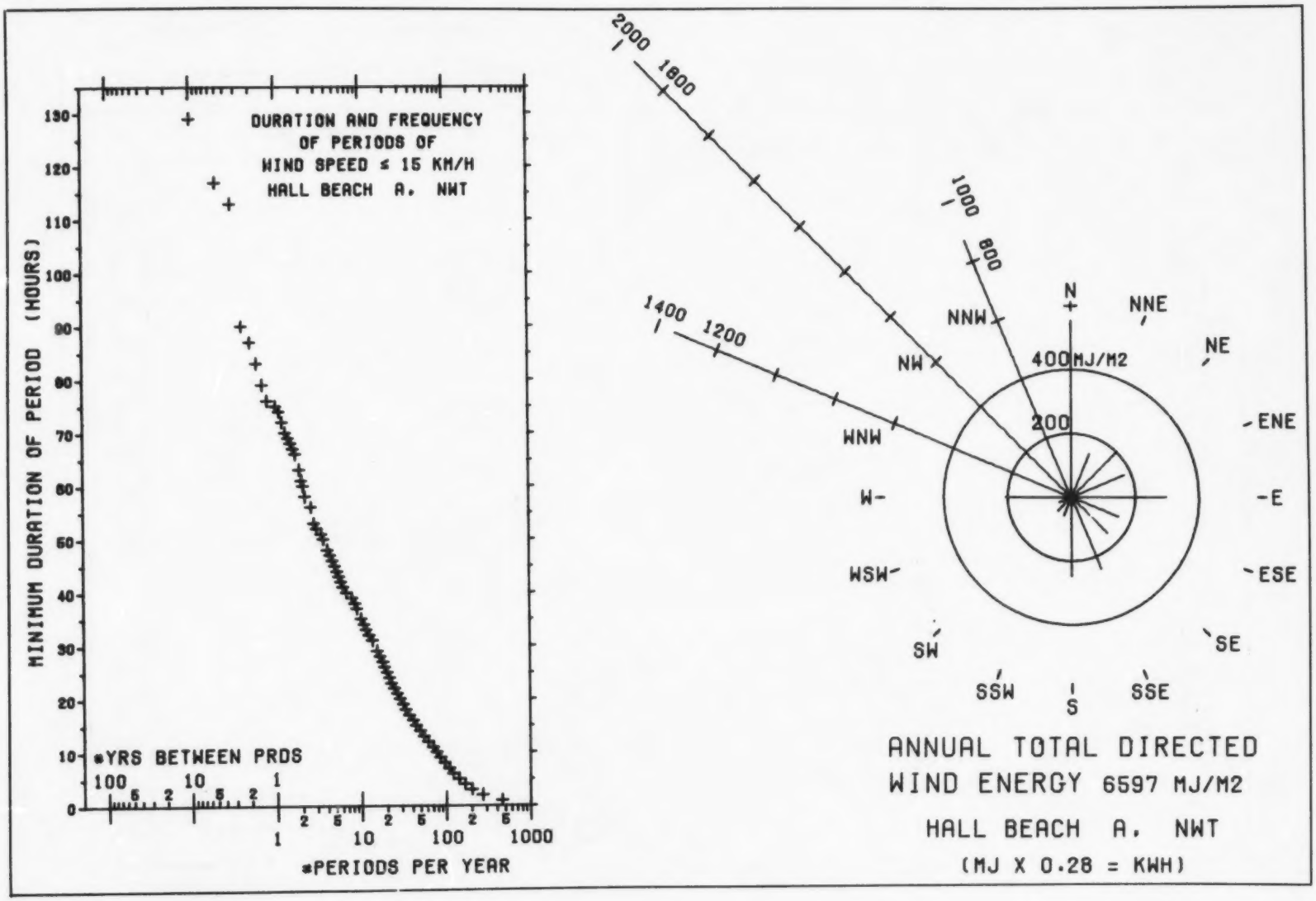

DURATION AND FREQUENCY
OF PERIODS OF
WIND SPEED ≤ 15 KM/H
HALL BEACH A. NWT
MINIMUM DURATION OF PERIOD (HOURS)
#YRS BETWEEN PRDS
100 10 1
#PERIODS PER YEAR
2000 1600 1200 1400 1000 800
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW
400 MJ/M2
200
ANNUAL TOTAL DIRECTED
WIND ENERGY 6597 MJ/M2
HALL BEACH A. NWT
(MJ X 0.28 = KWH)

Figure 53. Duration and frequency of winds ≤ 15 km/h for Hall Beach A, NWT.

Figure 54. Energy rose for Hall Beach A, NWT.

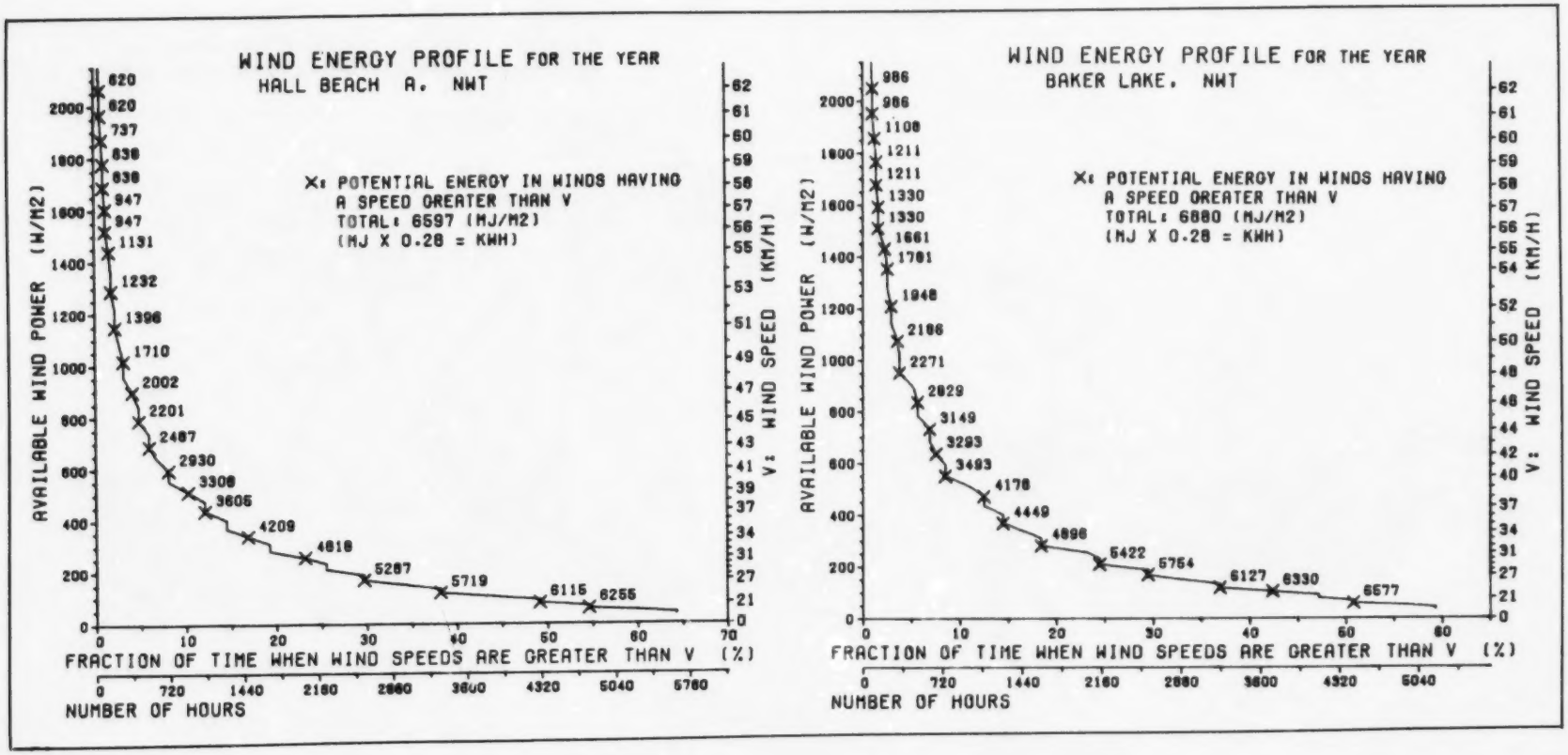


Figure 55. Annual wind-energy profile for Hall Beach A, NWT.

Figure 56. Annual wind-energy profile for Baker Lake, NWT.

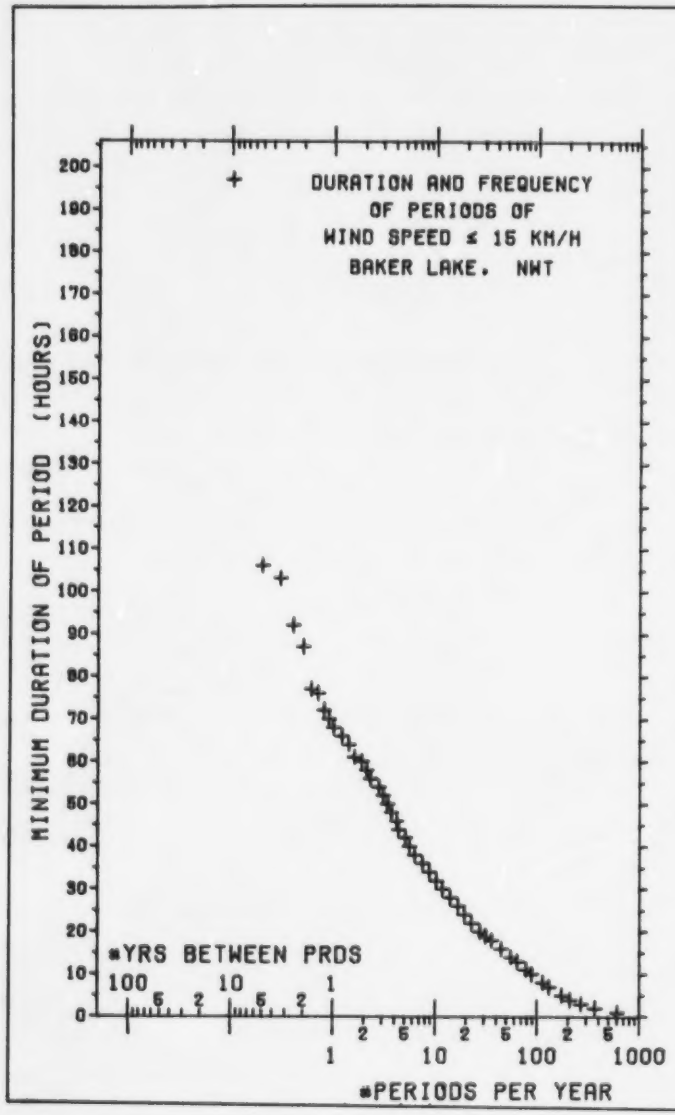


Figure 57. Duration and frequency of winds ≤ 15 km/h for Baker Lake, NWT.

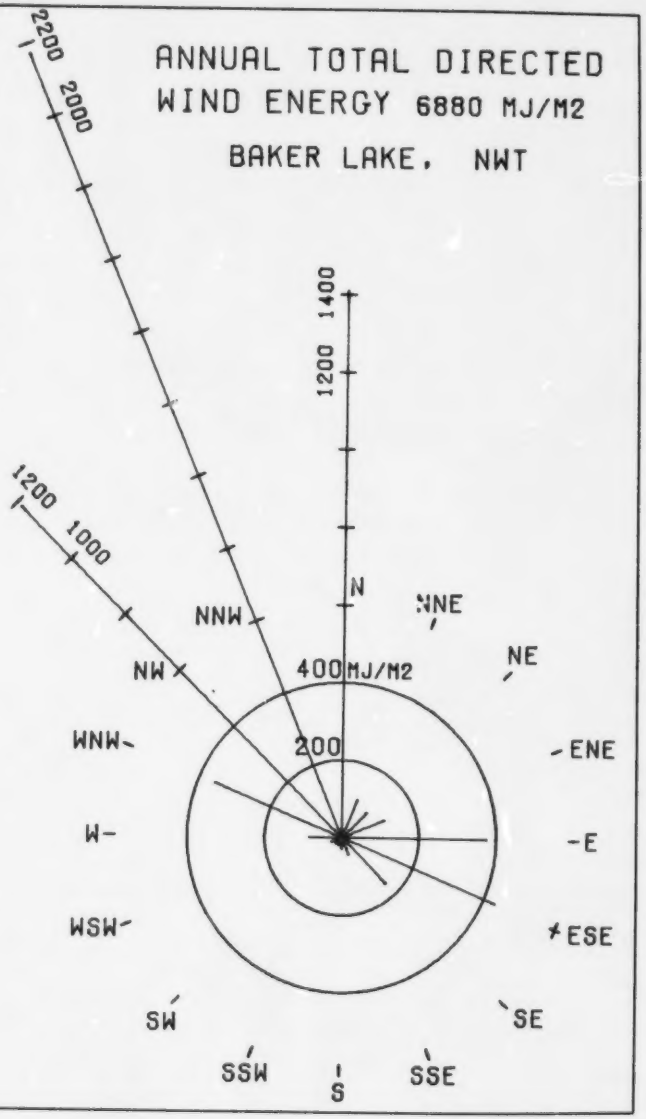


Figure 58. Energy rose for Baker Lake, NWT.

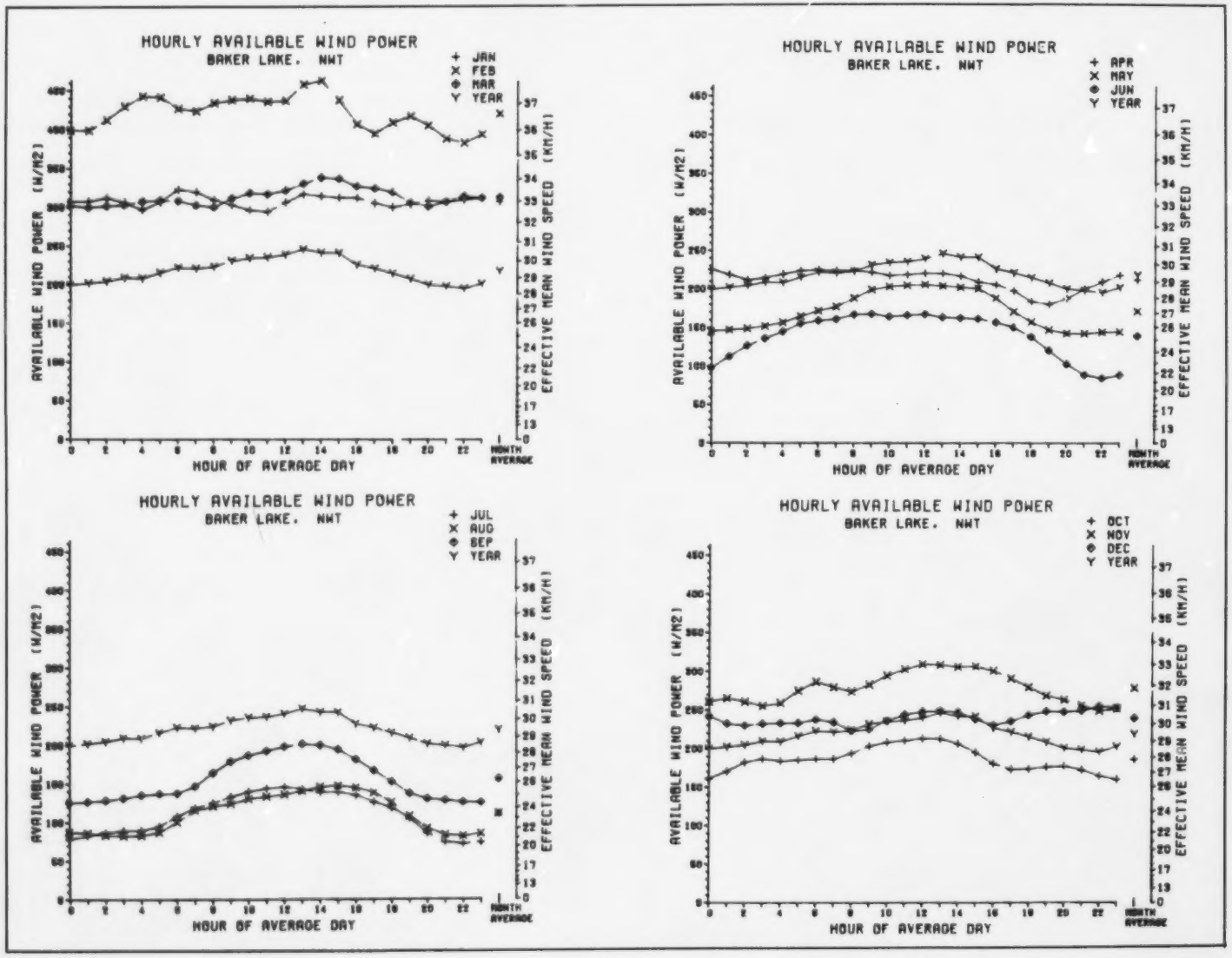


Figure 59. Hourly available wind power, Baker Lake, NWT.

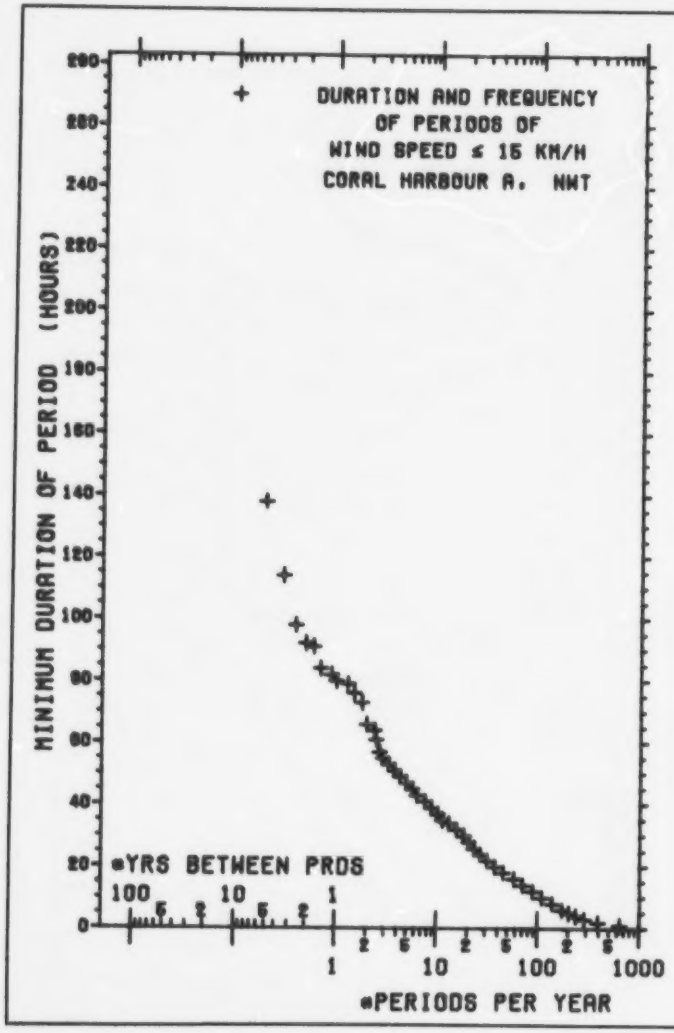


Figure 60. Duration and frequency of winds ⩽15 km/h for Coral Harbour A, NWT.

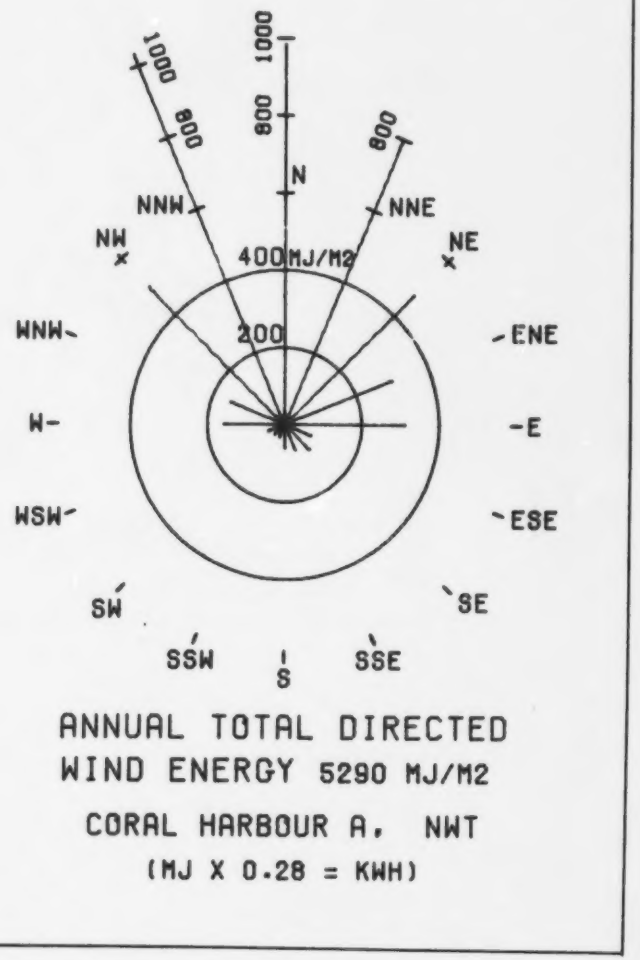


Figure 61. Energy rose for Coral Harbour A, NWT.

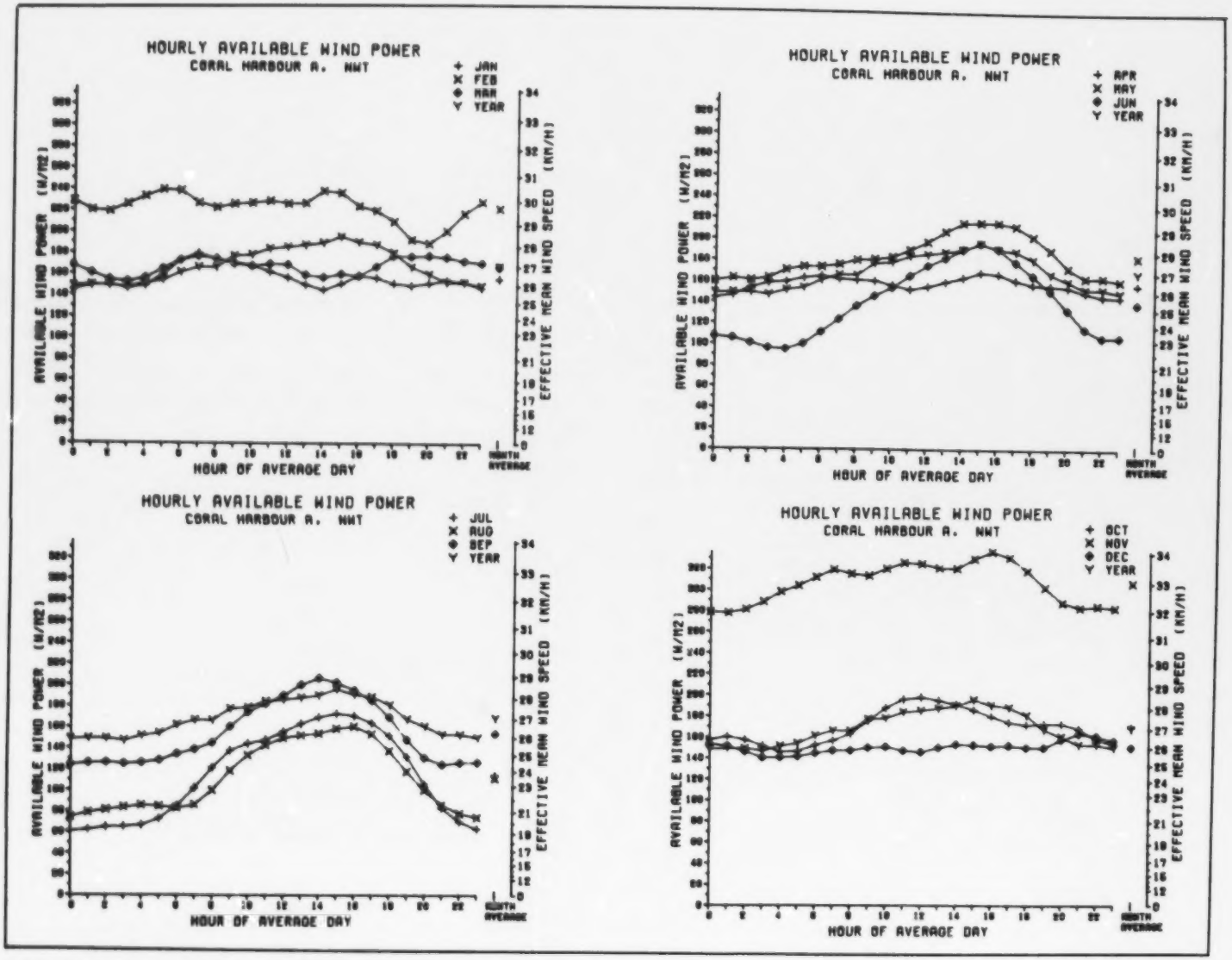


Figure 62. Hourly available wind power, Coral Harbour A, NWT.

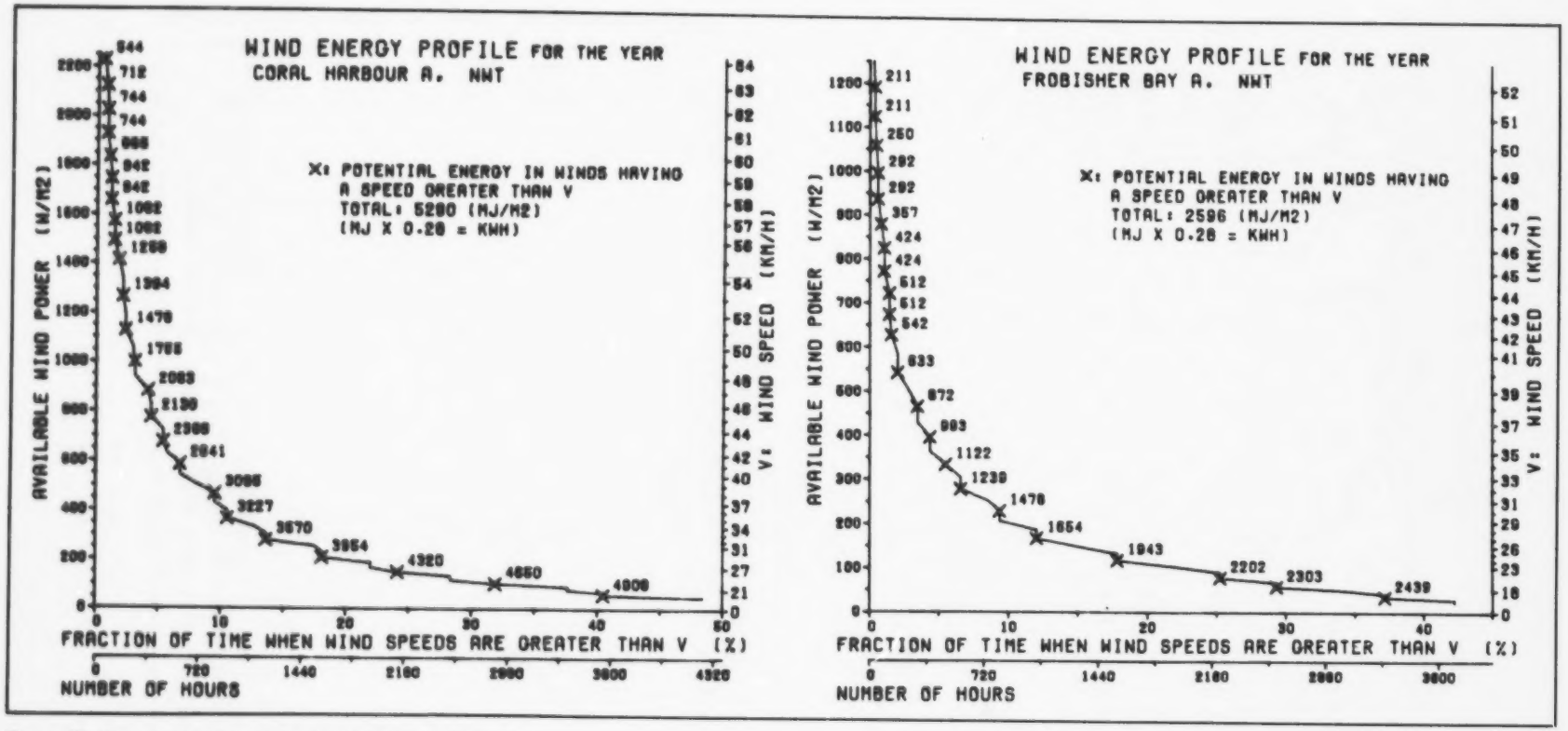

WIND ENERGY PROFILE FOR THE YEAR
CORAL HARBOUR A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING A SPEED GREATER THAN V
TOTAL: 5280 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS
WIND ENERGY PROFILE FOR THE YEAR
FROBISHER BAY A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING A SPEED GREATER THAN V
TOTAL: 2596 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 63. Annual wind-energy profile for Coral Harbour A, NWT.

Figure 64. Annual wind-energy profile for Frobisher Bay A, NWT.

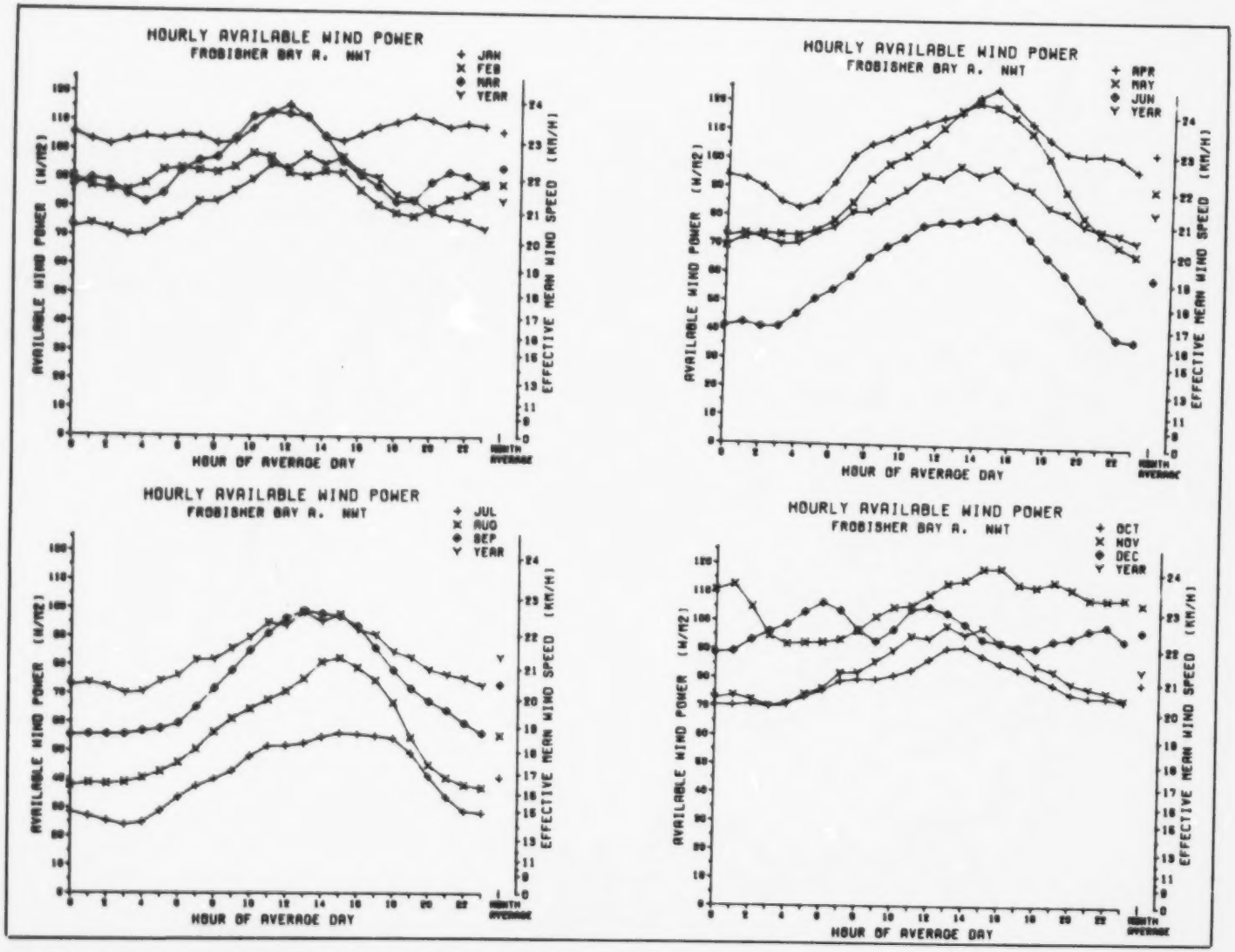


Figure 65. Hourly available wind power, Frobisher Bay A, N.W.T.

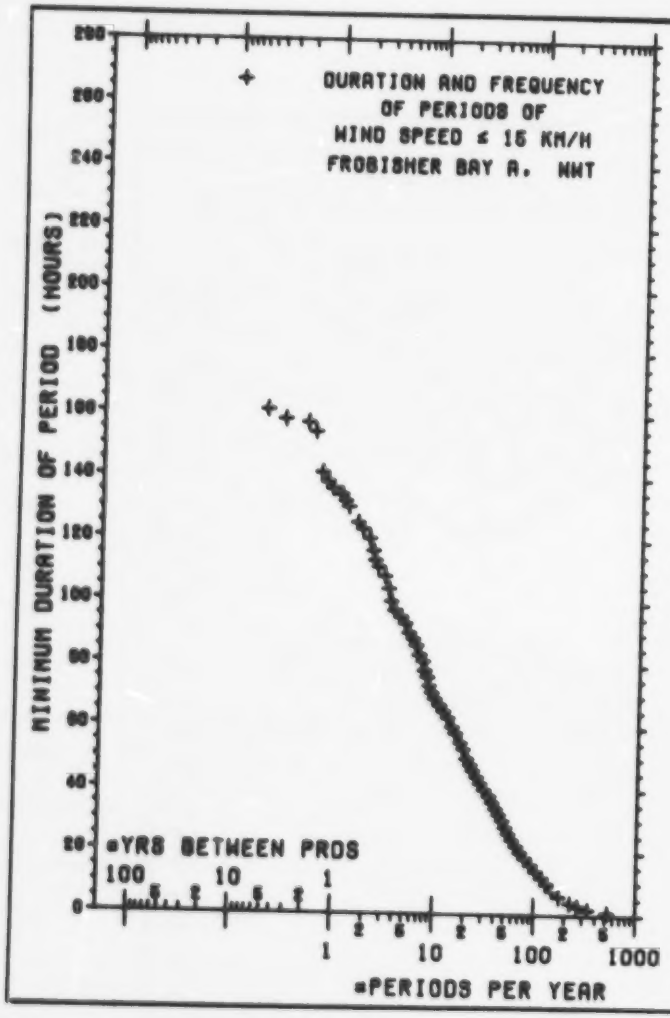


Figure 66. Duration and frequency of winds ≤ 15 km/h for Frobisher Bay A, NWT.

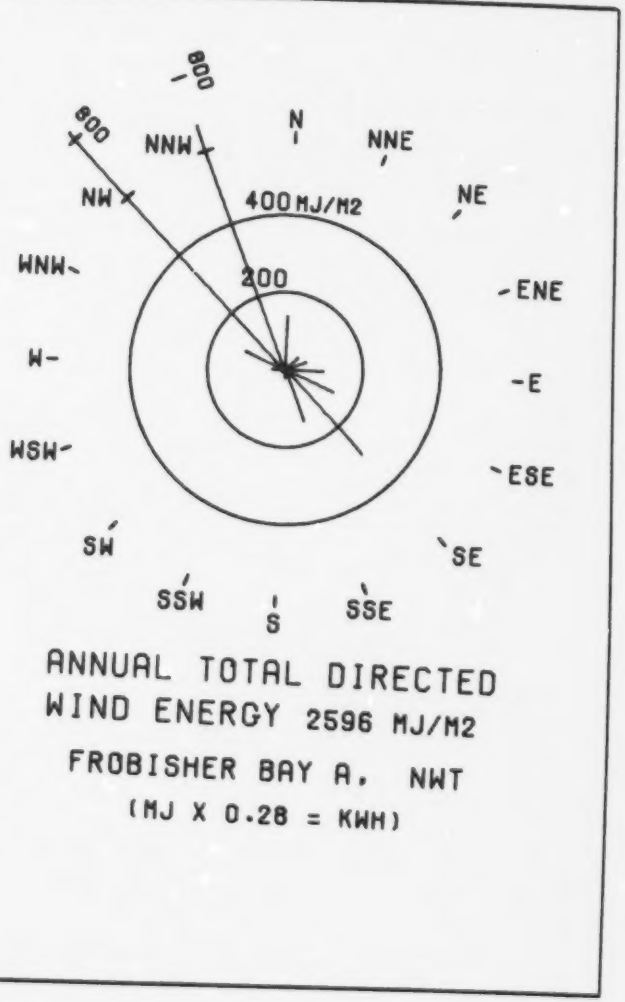


Figure 67. Energy rose for Frobisher Bay A, NWT.

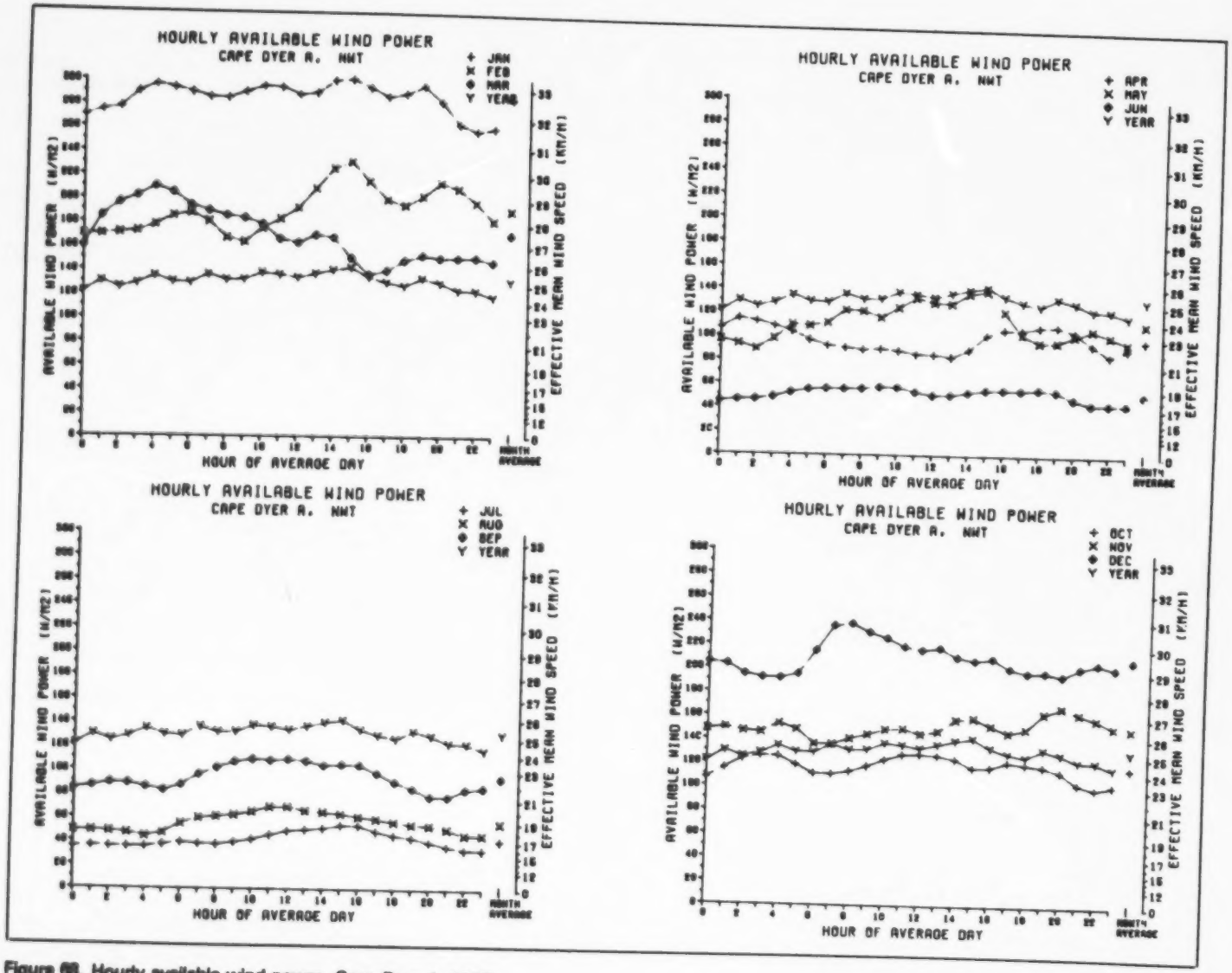


Figure 68. Hourly available wind power, Cape Dyer A, NWT.

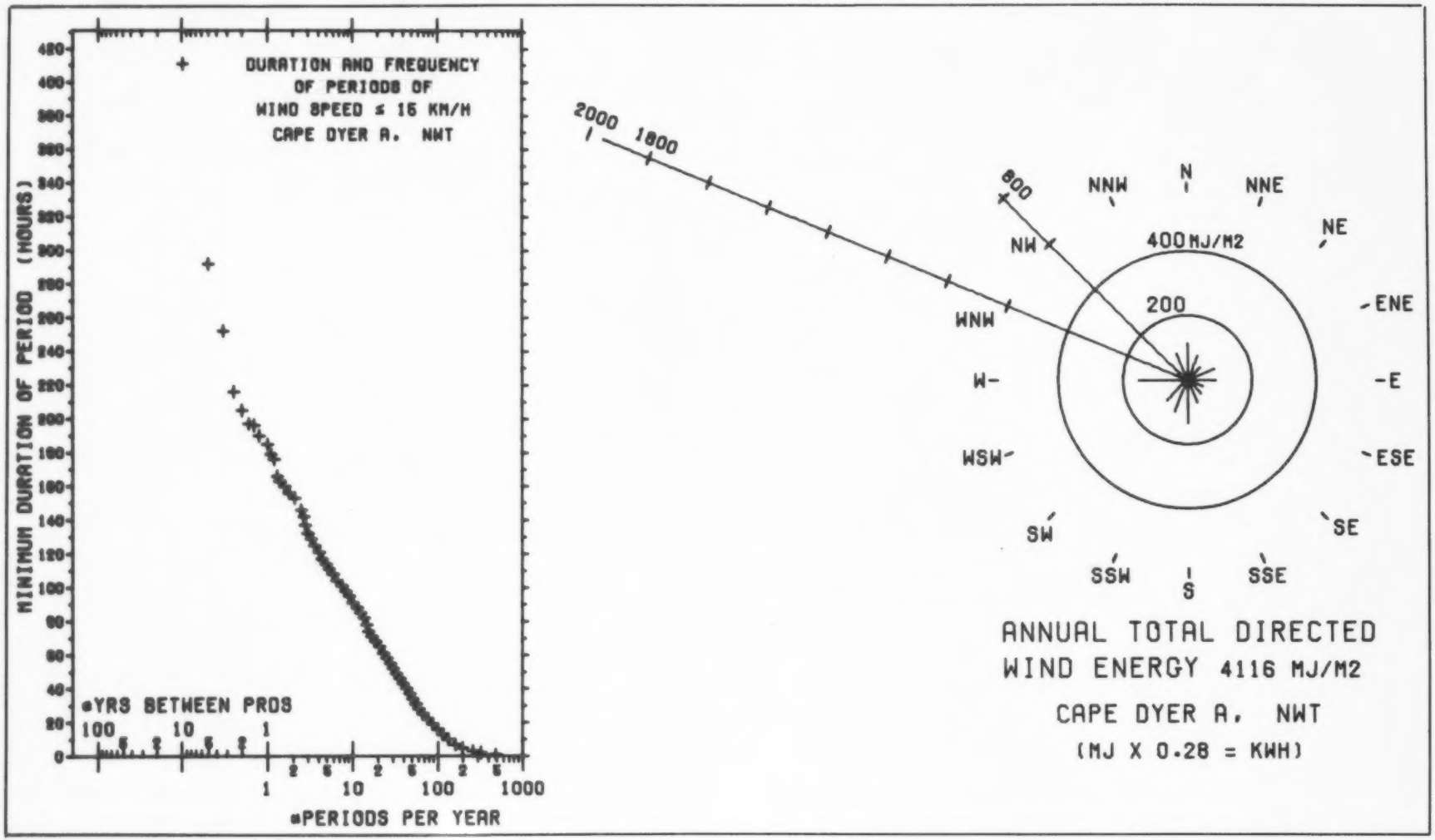


Figure 69. Duration and frequency of ≤ 15 km/h for Cape Dyer A, NWT.

Figure 70. Energy rose for Cape Dyer A, NWT.

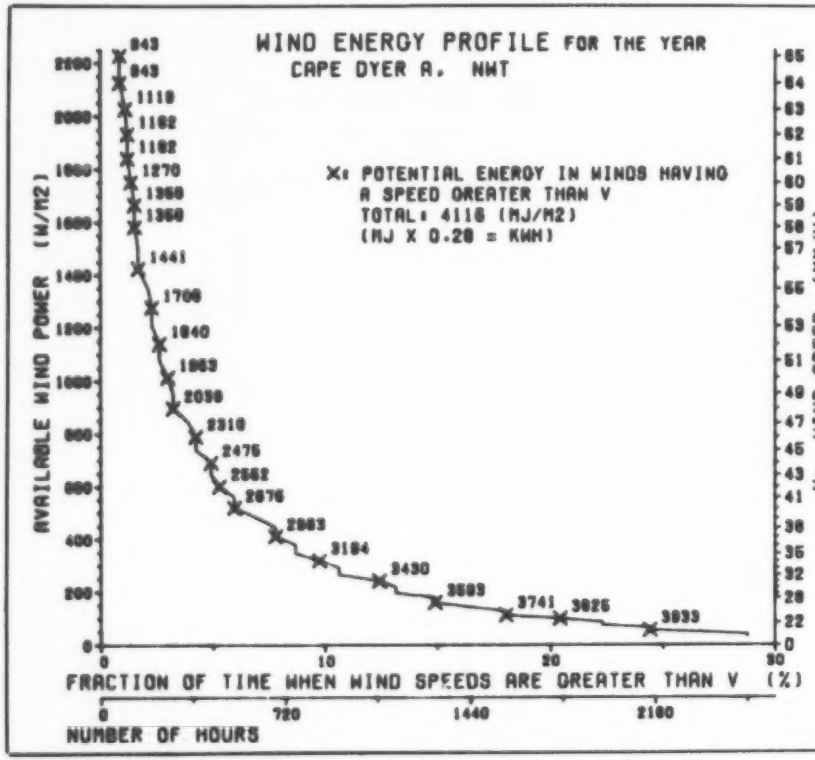

WIND ENERGY PROFILE FOR THE YEAR
CAPE DYER A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING
A SPEED GREATER THAN V
TOTAL: 4116 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 71. Annual wind-energy profile for Cape Dyer A, NWT.

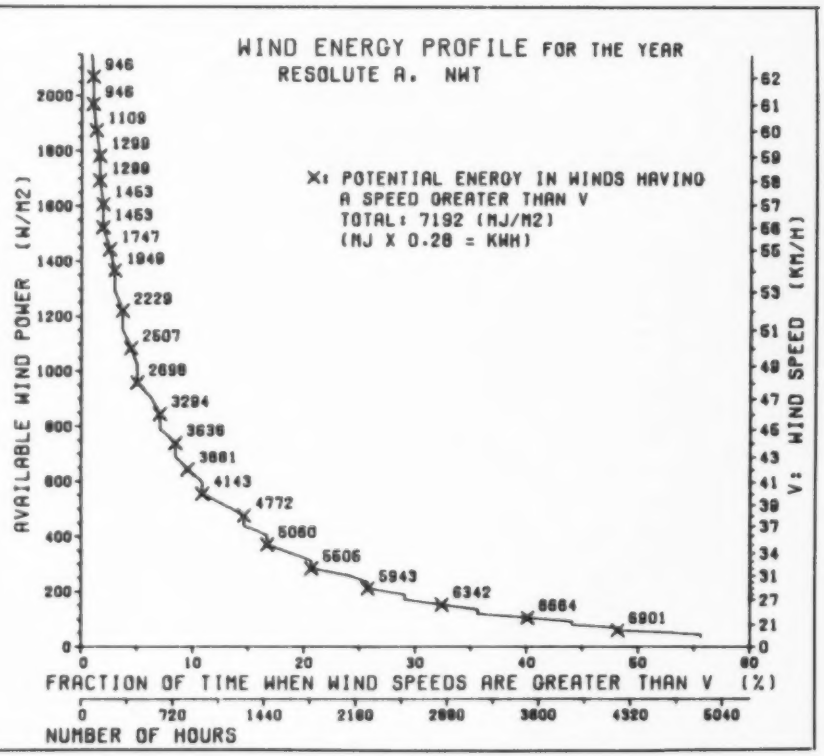

WIND ENERGY PROFILE FOR THE YEAR
RESOLUTE A. NWT
X: POTENTIAL ENERGY IN WINDS HAVING
A SPEED GREATER THAN V
TOTAL: 7192 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 72. Annual wind-energy profile for Resolute A, NWT.

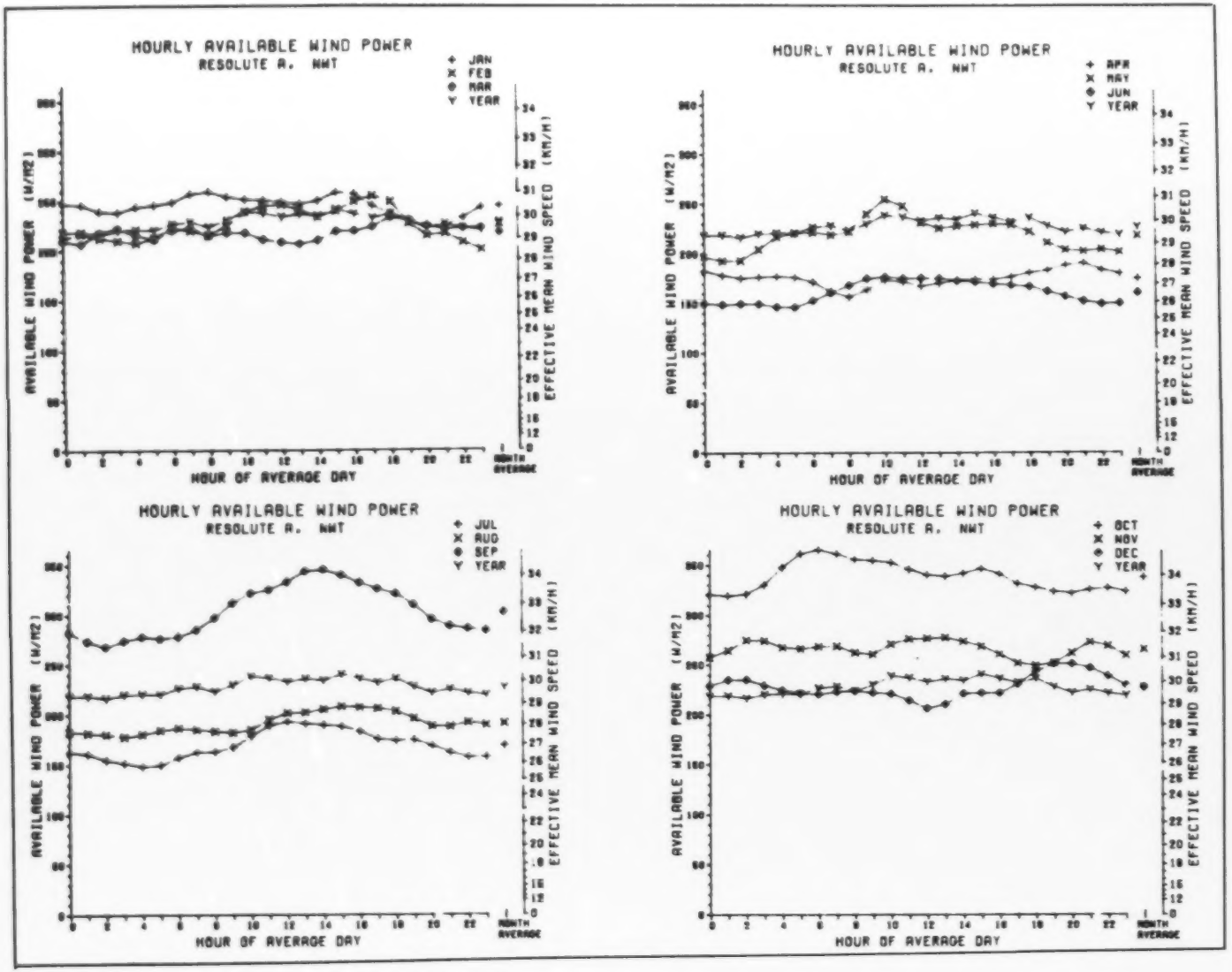


Figure 73. Hourly available wind power, Resolute A, NWT.

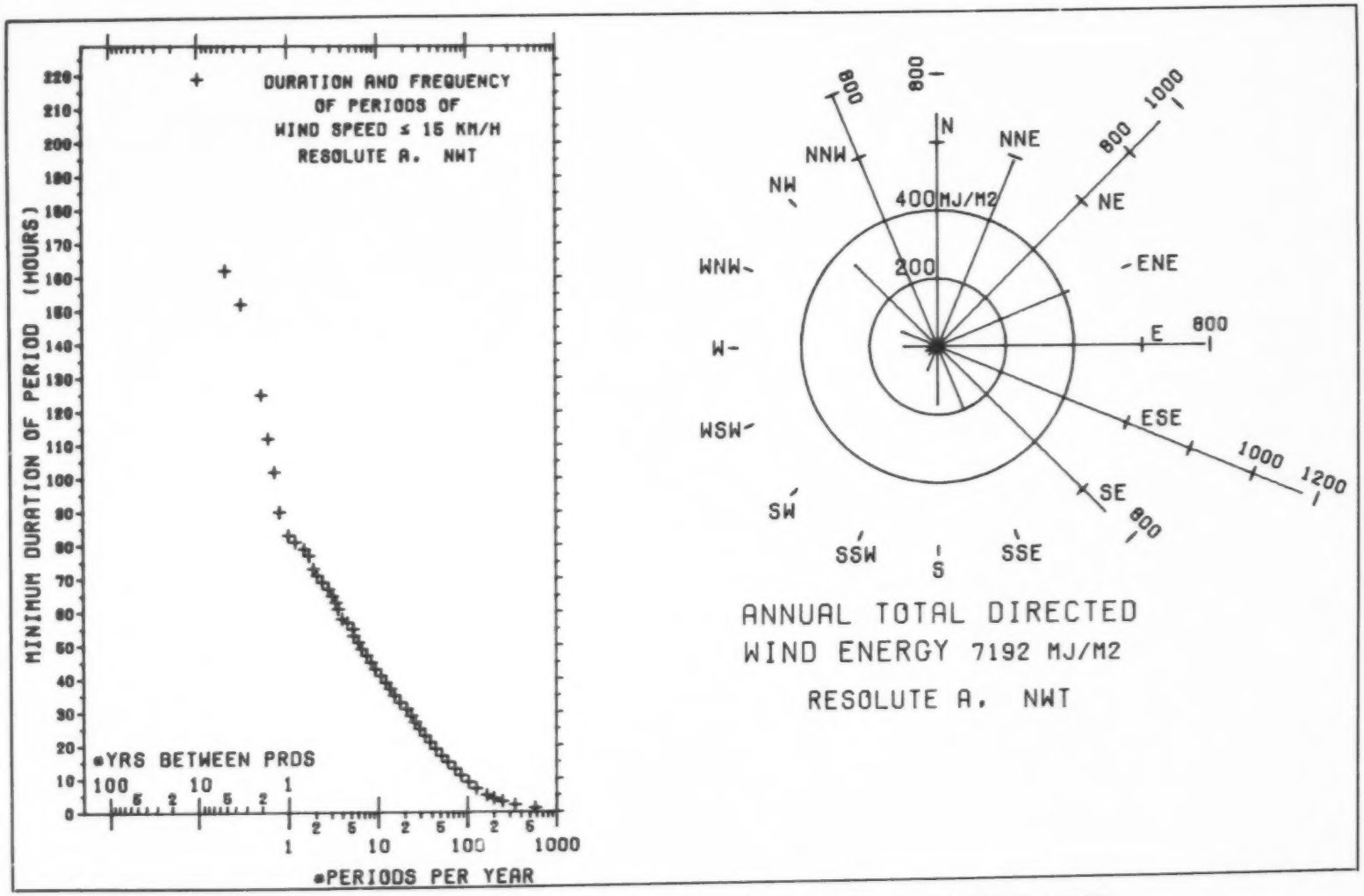


Figure 74. Duration and frequency of winds ≤ 15 km/h for Resolute A, NWT.

Figure 75. Energy rose for Resolute A, NWT.

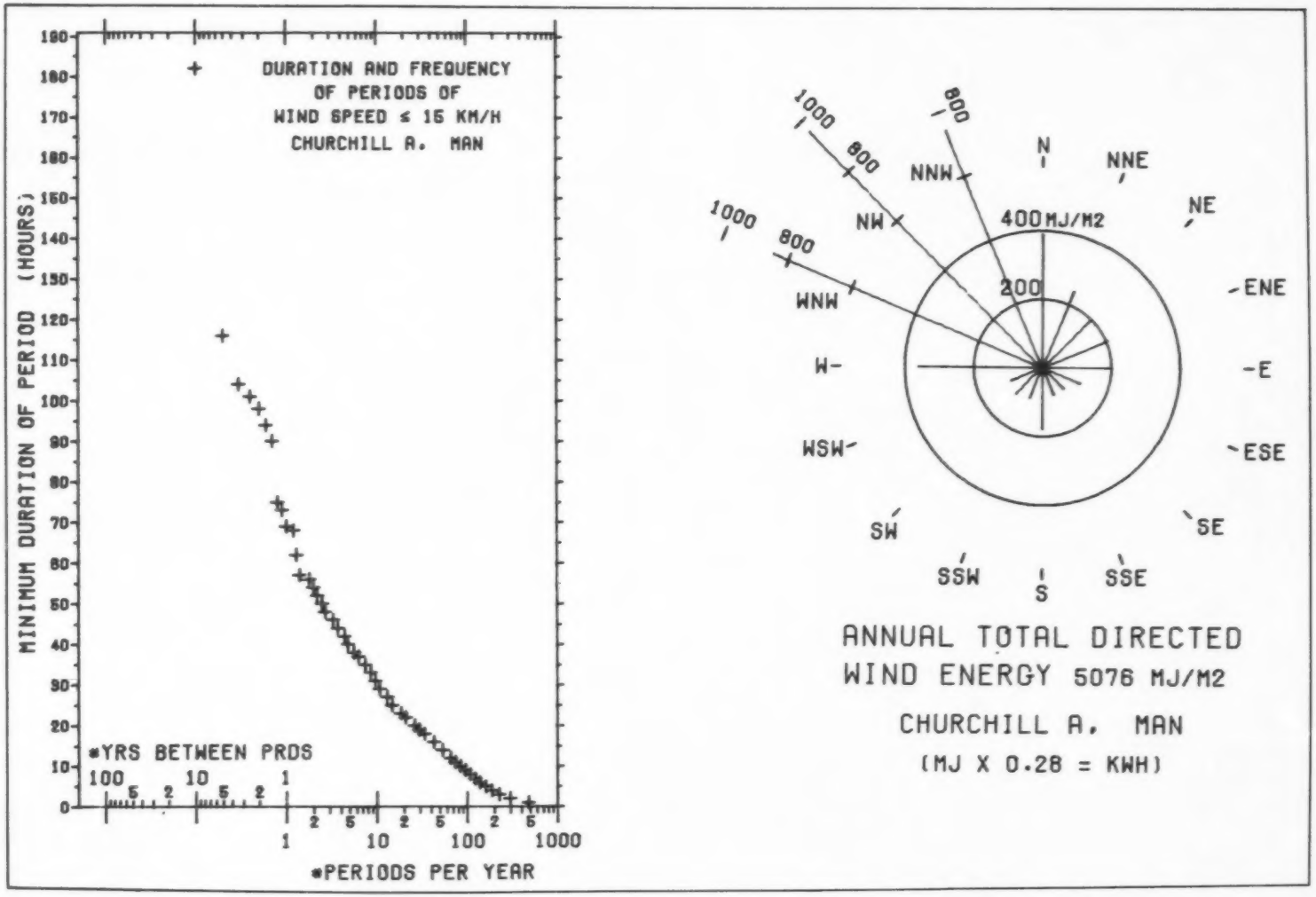


Figure 76. Duration and frequency of winds ≤ 15 km/h for Churchill A, Man.

Figure 77. Energy rose for Churchill A, Man.

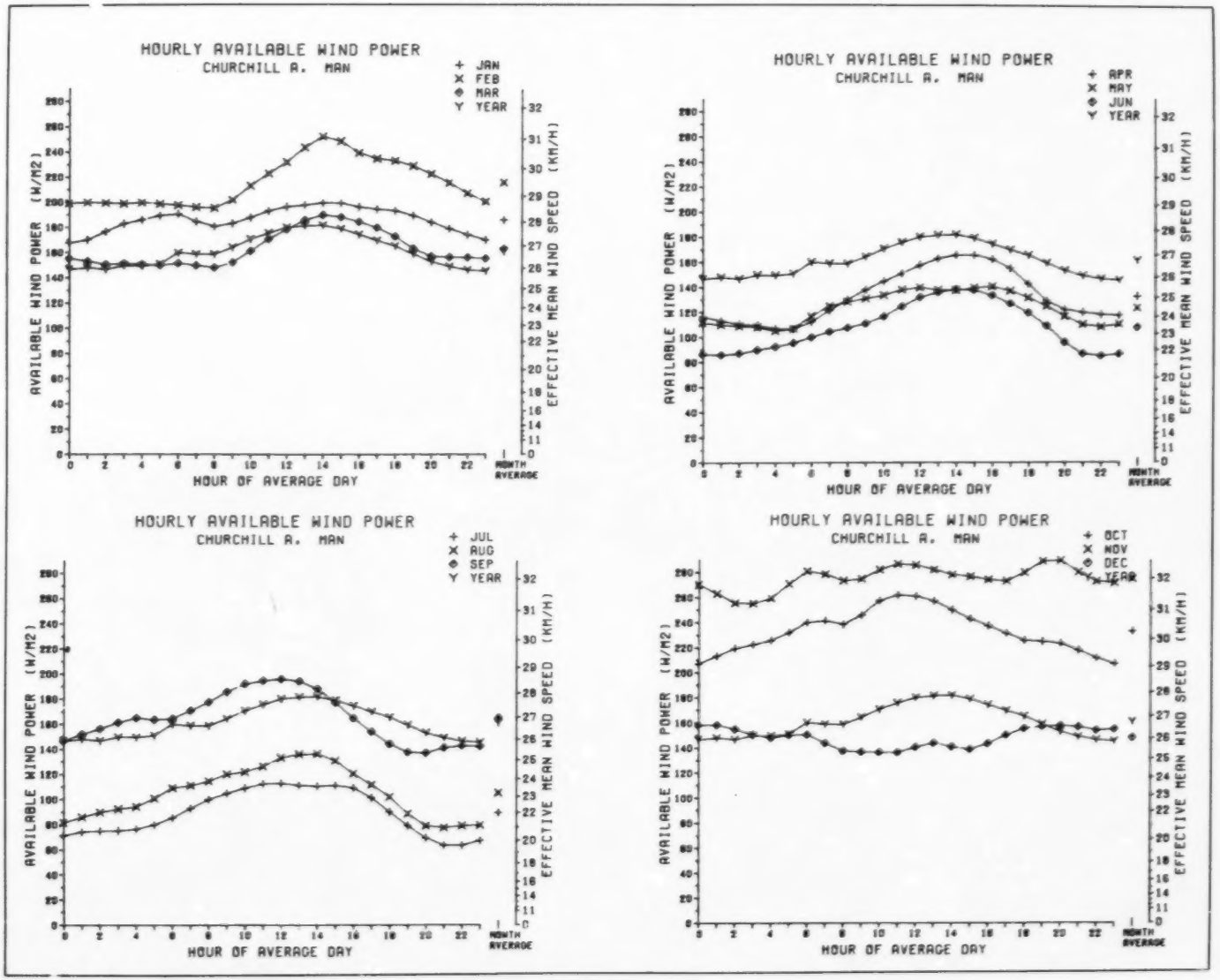


Figure 78. Hourly available wind power, Churchill A, Manitoba.

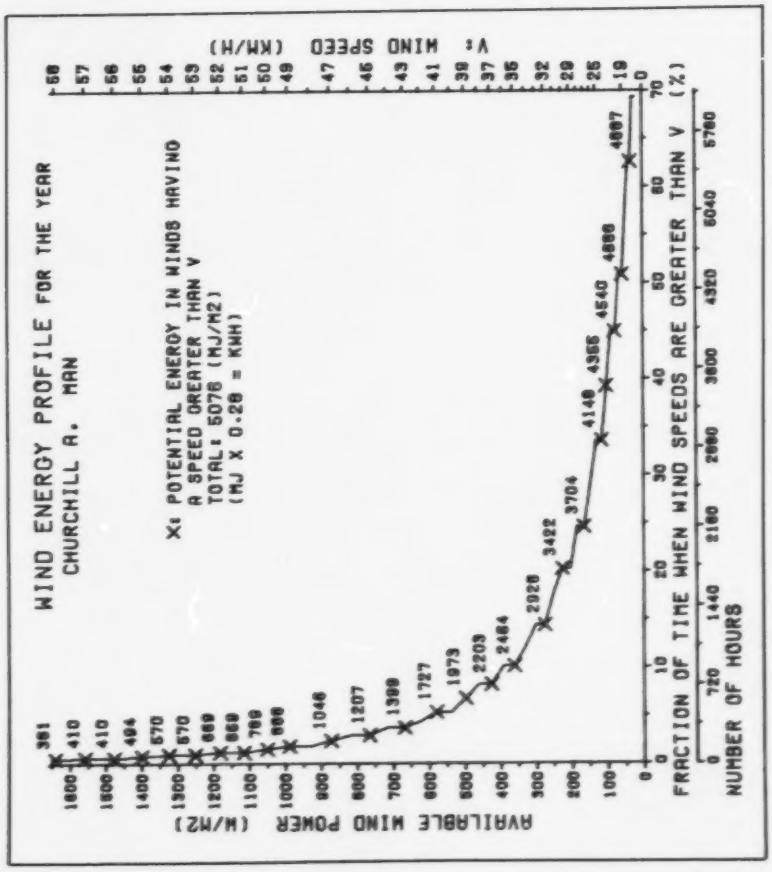

WIND ENERGY PROFILE FOR THE YEAR
CHURCHILL A. MAN
X: POTENTIAL ENERGY IN WINDS HAVING
A SPEED GREATER THAN V
TOTAL: 5076 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 79. Annual wind energy profile for Churchill A, Manitoba.

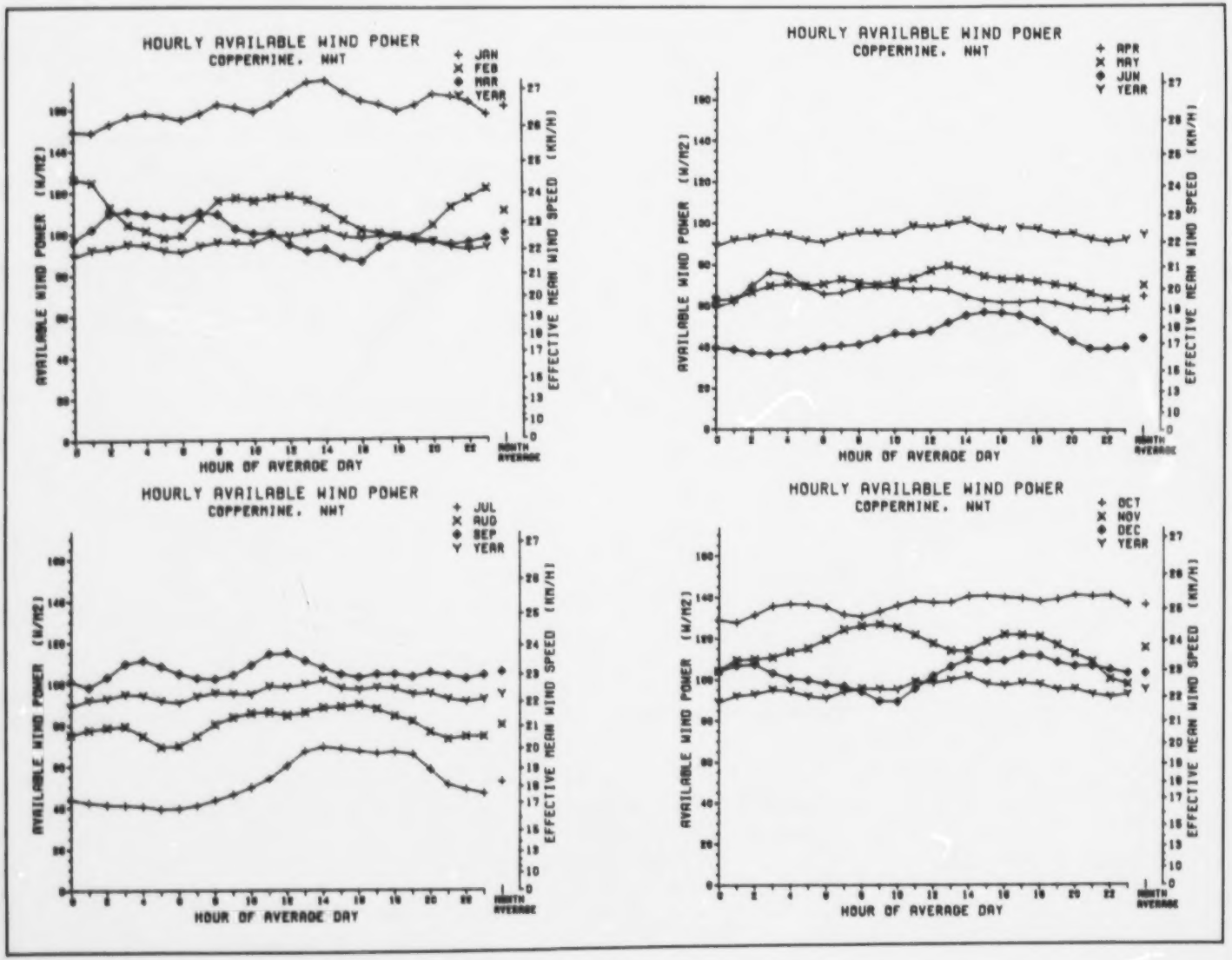


Figure 80 Hourly available wind power, Coppermine, N.W.T.

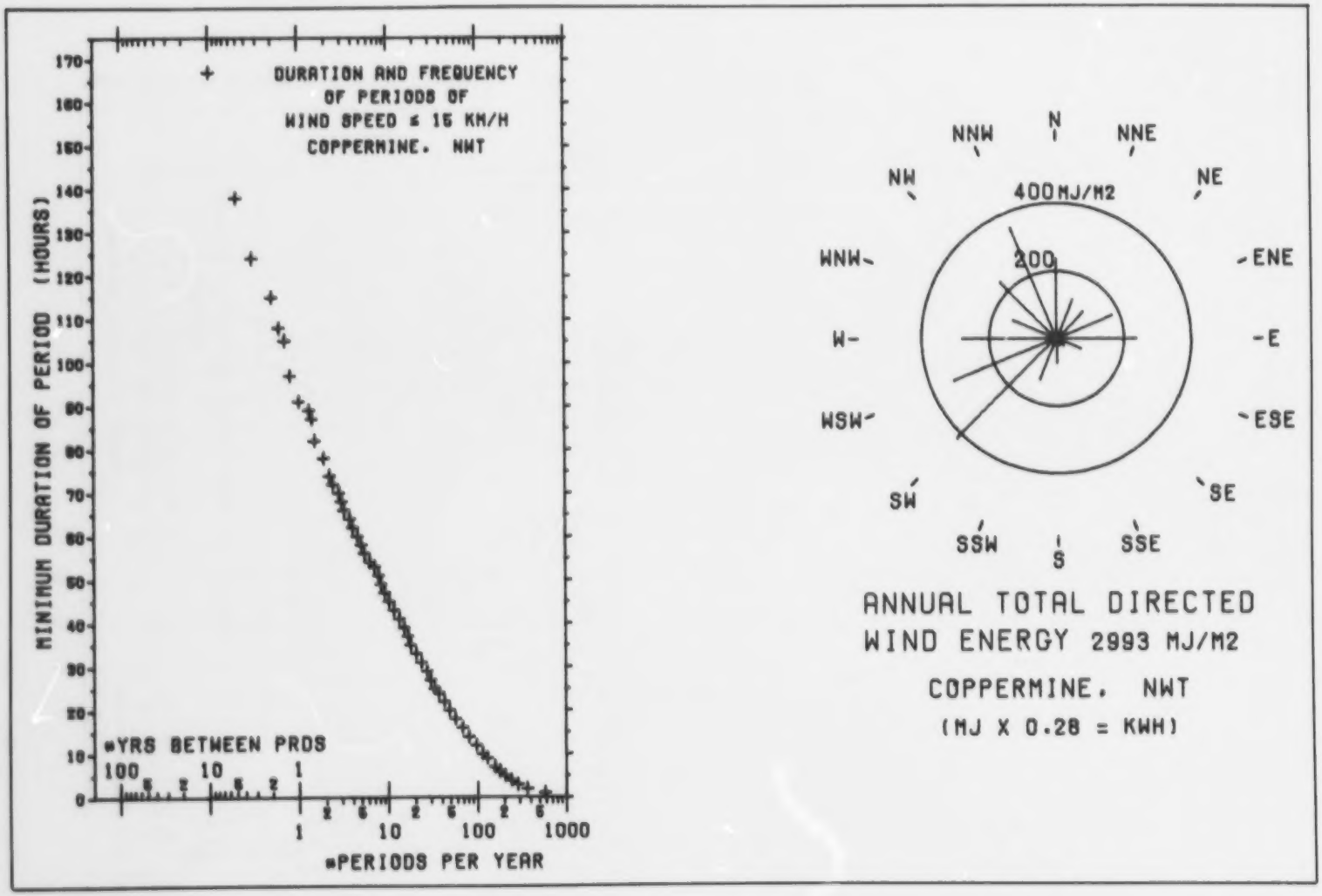


Figure 81 Duration and frequency of winds ≤ 15 km/h, Coppermine, N.W.T.

Figure 82 Energy rose, Coppermine, N.W.T.

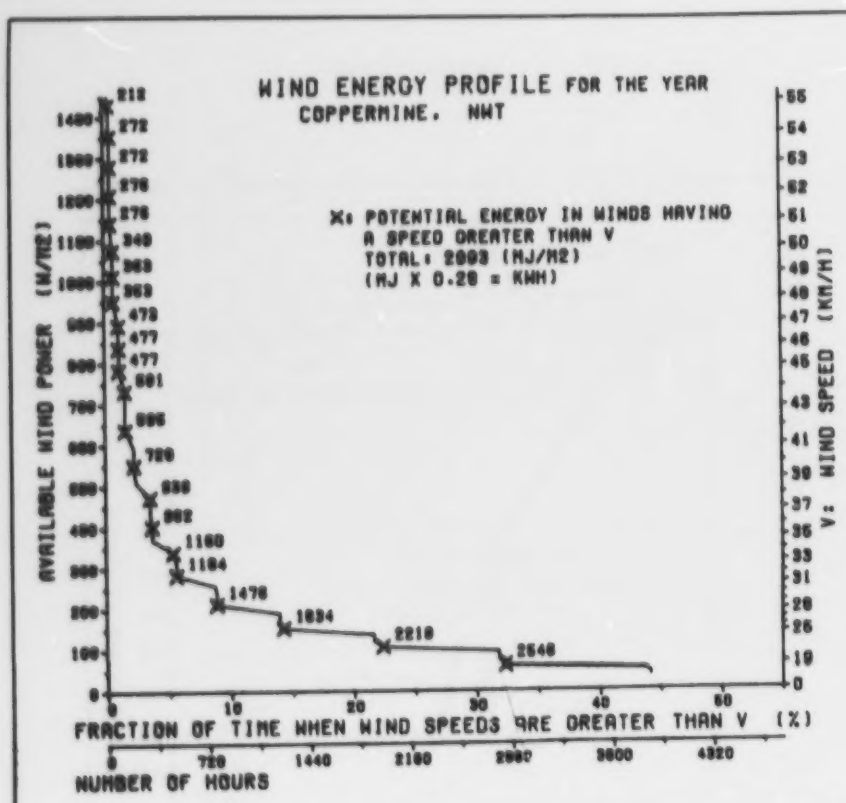

WIND ENERGY PROFILE FOR THE YEAR
COPPERMINE, NWT
X: POTENTIAL ENERGY IN WINDS HAVING
A SPEED GREATER THAN V
TOTAL: 2093 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 83 Annual wind-energy profile, Coppermine, N.W.T.

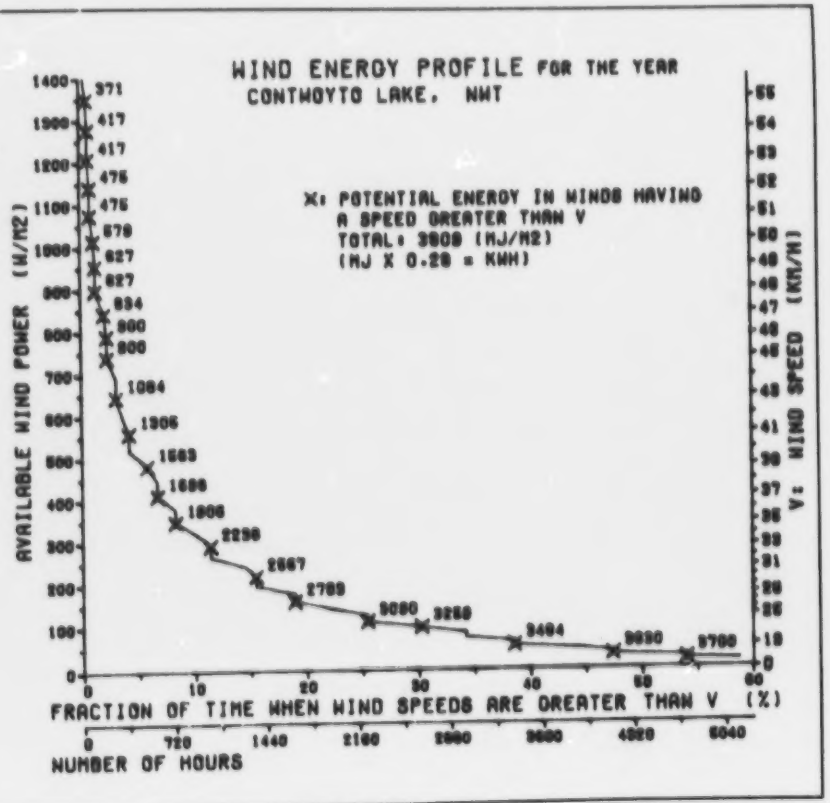

WIND ENERGY PROFILE FOR THE YEAR
CONTWOYTO LAKE, NWT
X: POTENTIAL ENERGY IN WINDS HAVING
A SPEED GREATER THAN V
TOTAL: 3808 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 84 Annual wind-energy profile, Contwoyto Lake, N.W.T.

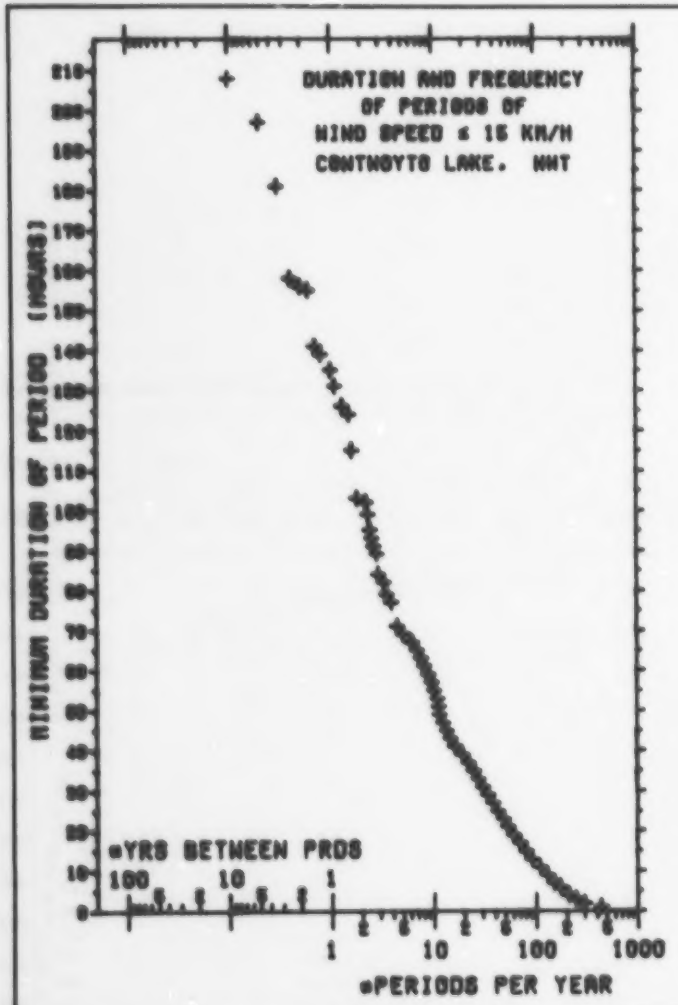


Figure 85 Duration and frequency of winds ≤ 15 km/h, Contwoyto Lake, N.W.T.

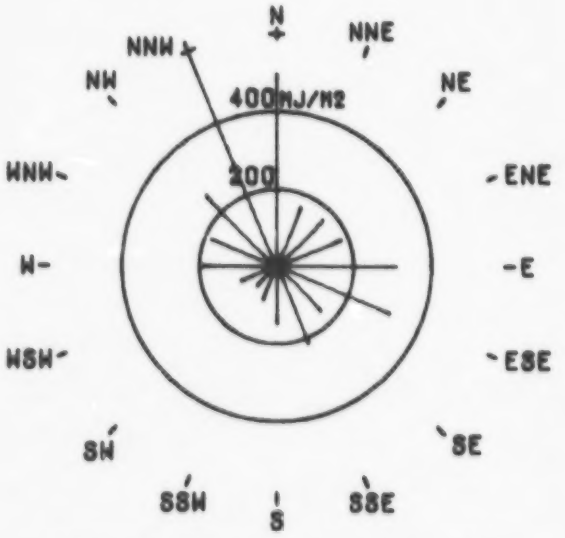


Figure 86 Energy rose, Contwoyto Lake, N.W.T.

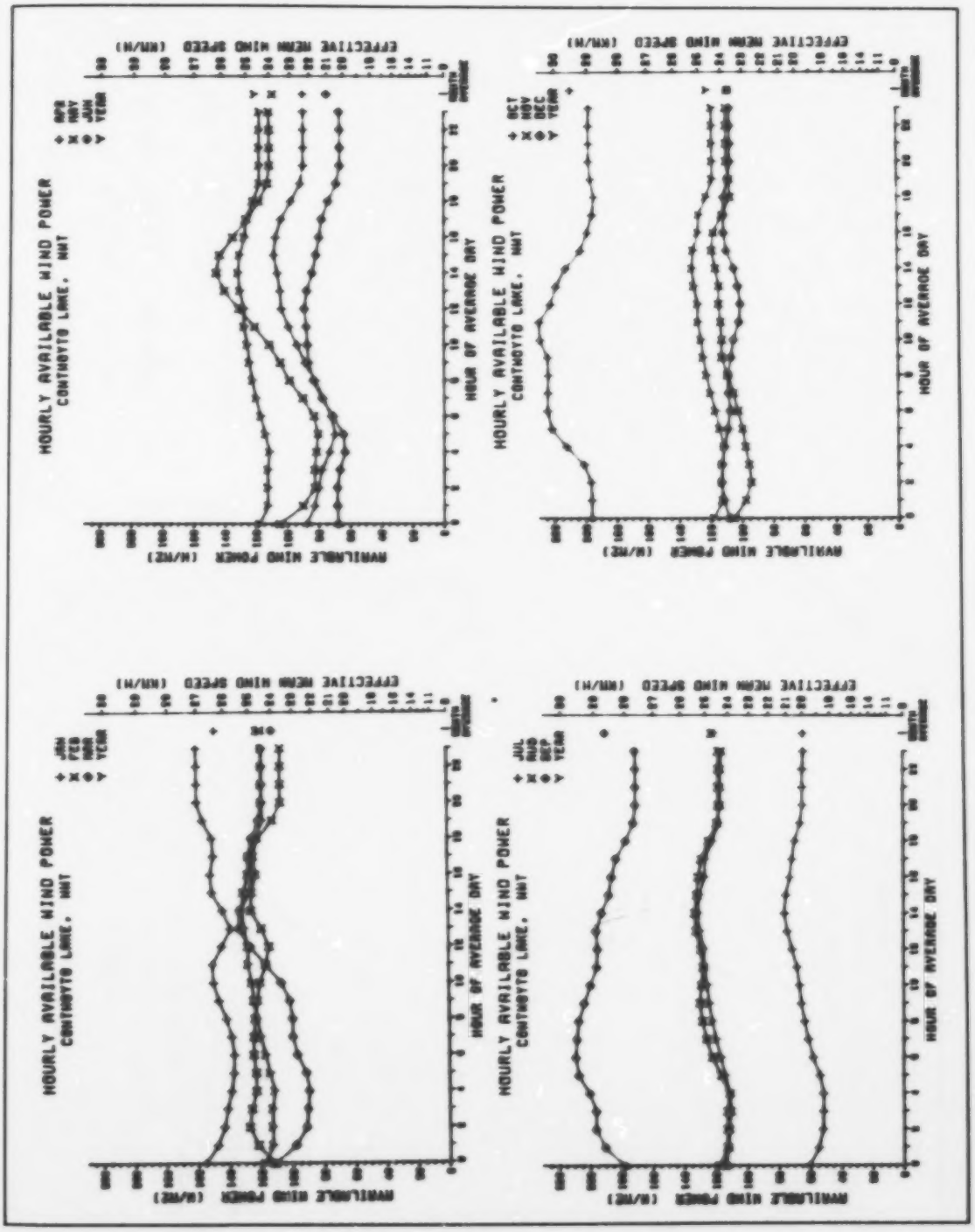


Figure 87 Hourly available wind power, Contwoyto Lake, N.W.T.

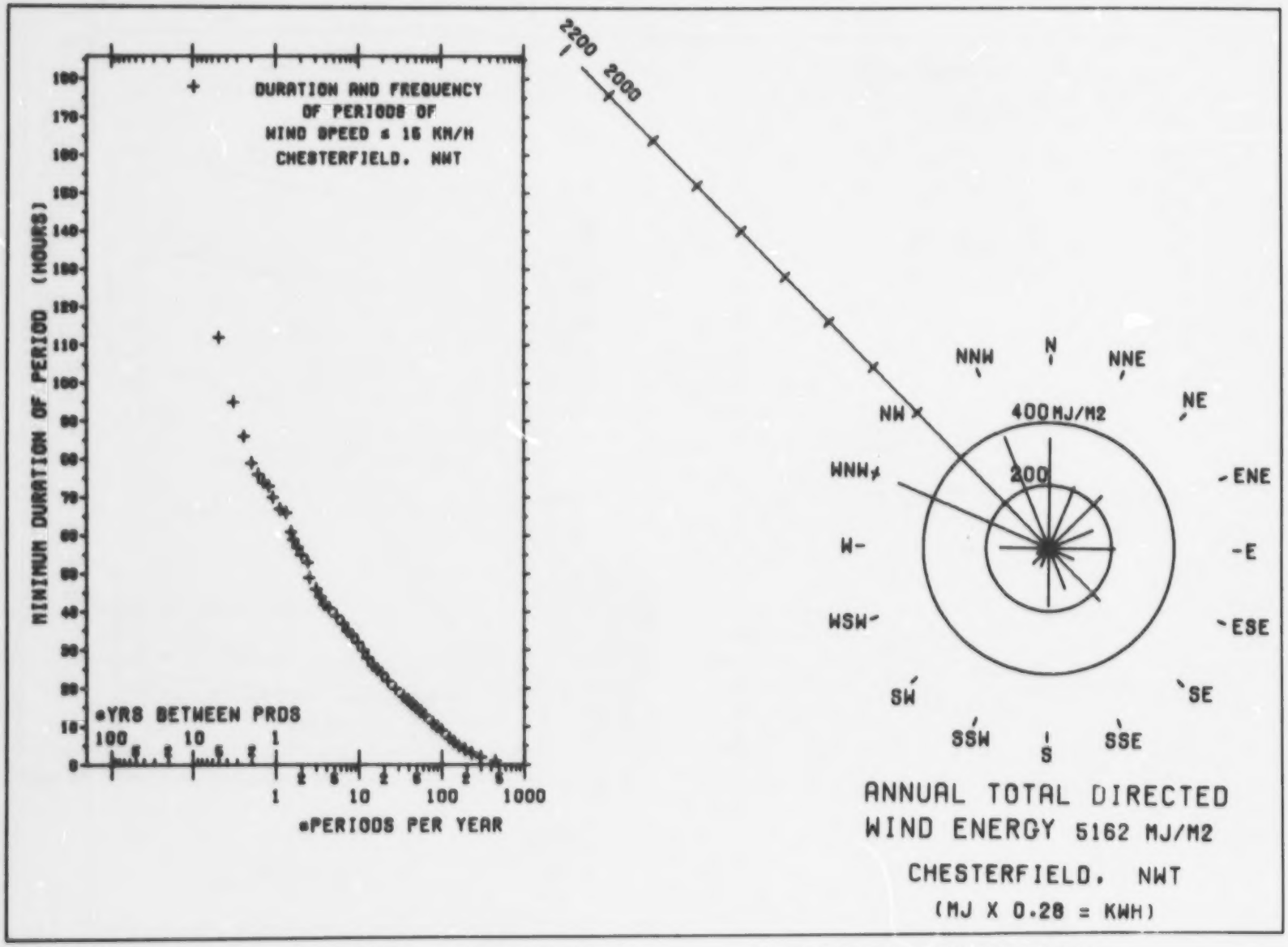


Figure 88 Duration and frequency of winds ≤ 15 km/h, Chesterfield, N.W.T.

Figure 89 Energy rose, Chesterfield, N.W.T.

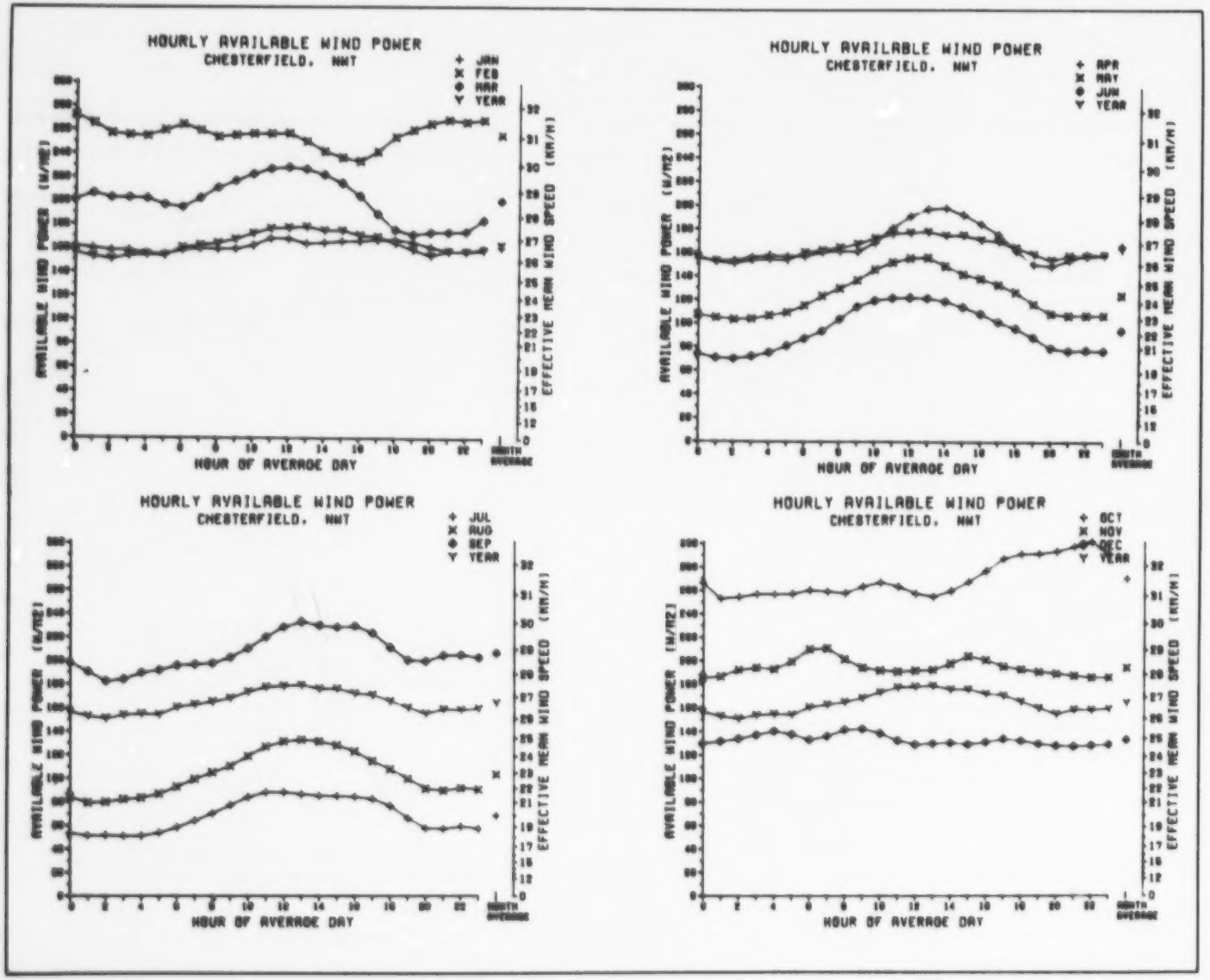


Figure 90 Hourly available wind power, Chesterfield, N.W.T.

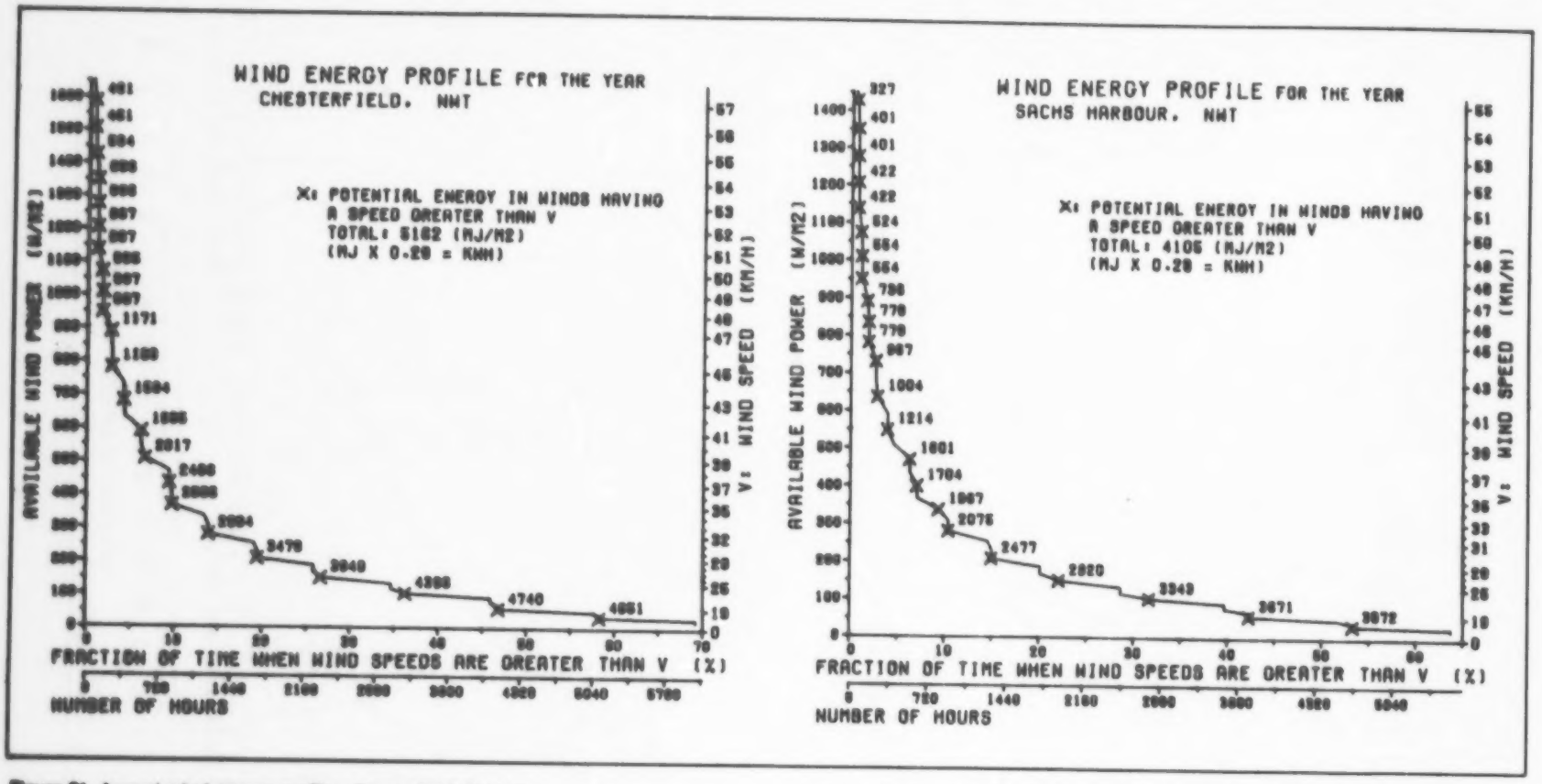

WIND ENERGY PROFILE FOR THE YEAR
CHESTERFIELD. NWT
X: POTENTIAL ENERGY IN WINDS HAVING
A SPEED GREATER THAN V
TOTAL: 5162 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS
WIND ENERGY PROFILE FOR THE YEAR
SACHS HARBOUR. NWT
X: POTENTIAL ENERGY IN WINDS HAVING
A SPEED GREATER THAN V
TOTAL: 4105 (MJ/M2)
(MJ X 0.28 = KWH)
AVAILABLE WIND POWER (W/M2)
V: WIND SPEED (KM/H)
FRACTION OF TIME WHEN WIND SPEEDS ARE GREATER THAN V (%)
NUMBER OF HOURS

Figure 91 Annual wind-energy profile, Chesterfield, N.W.T.

Figure 92 Annual wind-energy profile, Sachs Harbour, N.W.T.

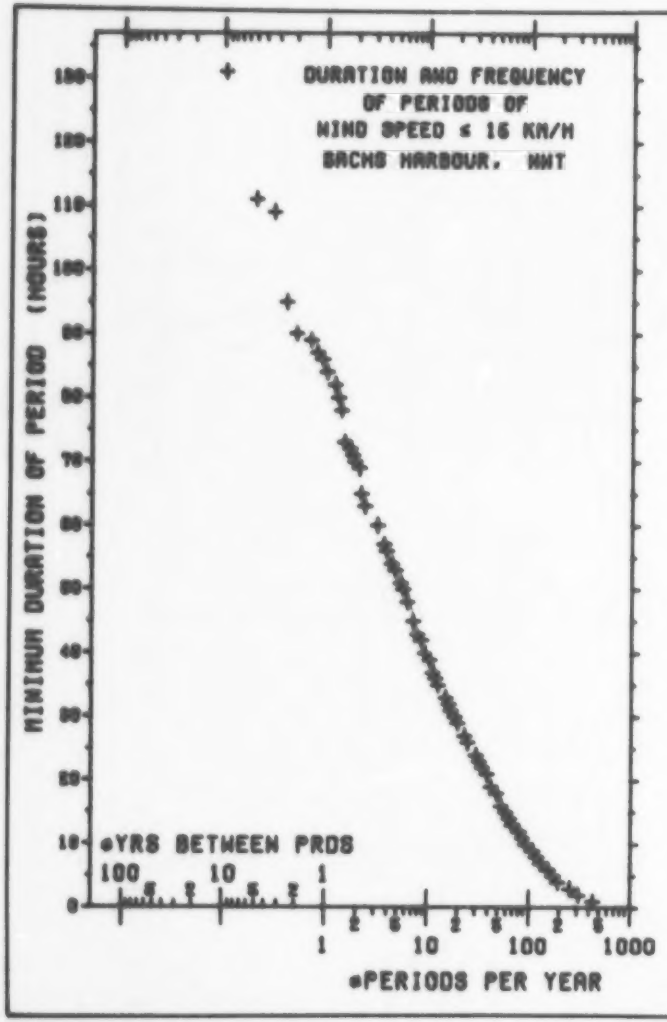


Figure 93 Duration and frequency of winds ≤ 16 km/h, Sachs Harbour, N.W.T.

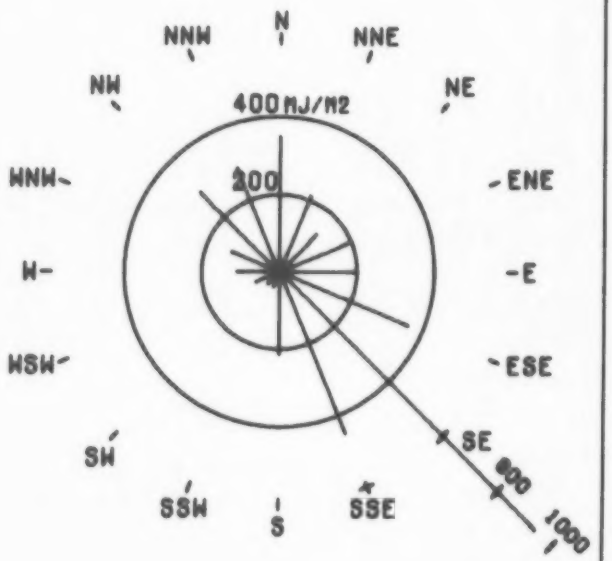


Figure 94 Energy rose, Sachs Harbour, N.W.T.

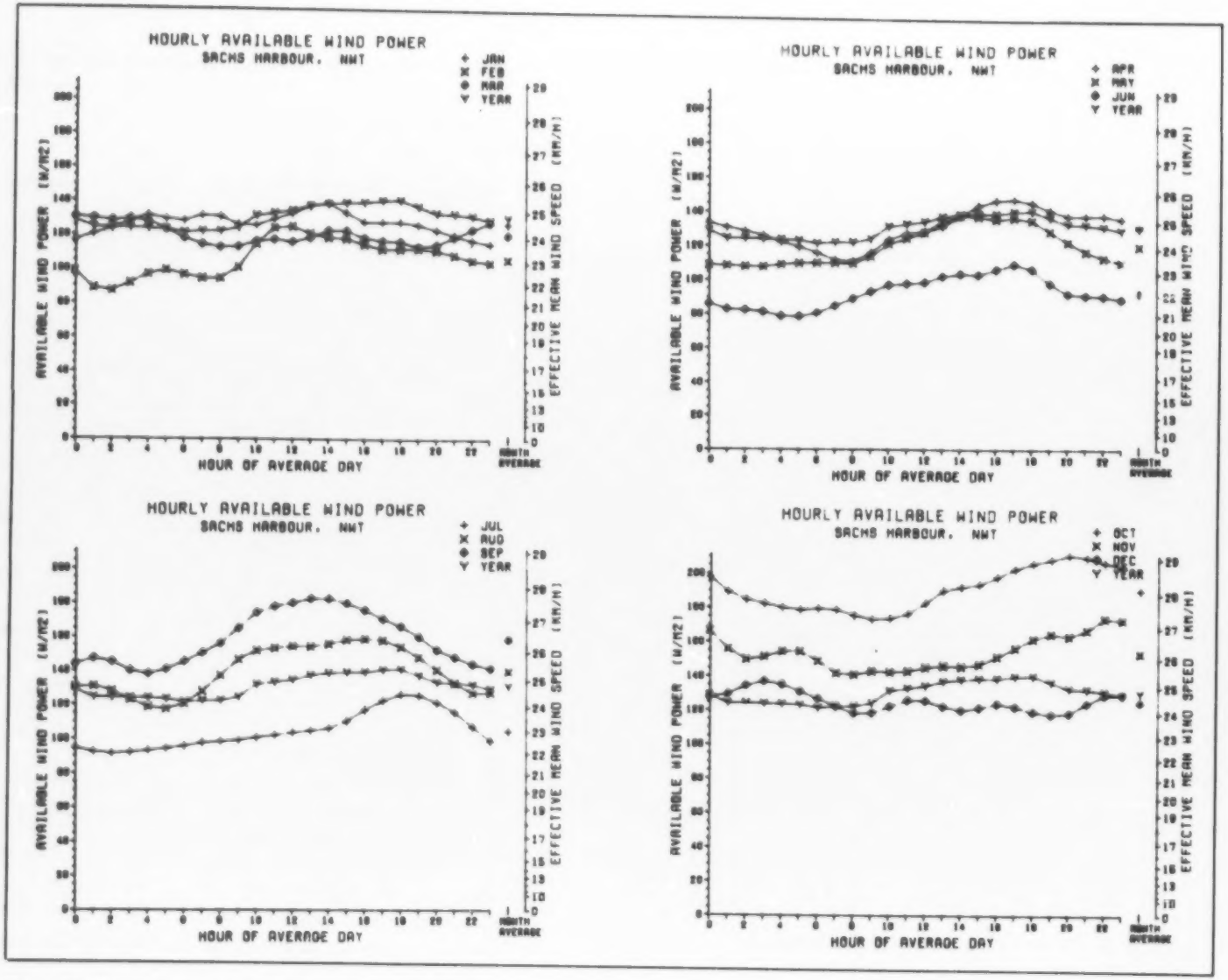


Figure 96 Hourly available wind power, Sachs Harbour, N.W.T.

6. Site Selection for Wind Machines

6.1 INTRODUCTION

Site selection is a critical phase in successfully using the wind resource. Improper siting has caused failures in the past and will, undoubtedly, contribute to failures in the future. The basic objective of site selection is twofold: to locate machines in places where they will extract the optimum energy from the wind stream, and to avoid places where physical hazards interfere with the efficient operation of the machine.

This report tries to shed light on the first objective – to provide data for the assessment of the wind resource. Even in those areas with good wind-energy potential, however, all sites are not equally good. Very poor sites exist in regions that are generally windy. This makes careful attention to site selection imperative.

Actual site assessment and selection may be relatively simple and inexpensive, or it may be complicated and costly. The effort and expense involved in this procedure depends, in part, on the size and initial cost of the machine. It is beyond the scope of this report to deal with this subject in detail. The World Meteorological Organization Technical Note No. 175 (1981) has excellent and practical suggestions for siting wind machines.

6.2 CONSIDERATIONS IN SITE SELECTION

This section discusses briefly the important steps and considerations involved in determining the most suitable site for a wind-energy system. The emphasis is on small and medium sized machines. Site selection for large machines may be exceedingly complicated and costly involving numerical and physical modelling in addition to the steps outlined in this section.

Taken in sequence, the suggested steps for selecting a site are:

1. Initial assessment.
2. Qualitative site assessment.
3. Topographical considerations.
4. Wind prospecting.
5. The energy rose.
6. Physical considerations.
7. Hazard evaluation.

6.2.1 Initial Assessment

The main purpose of the Mean Annual Wind-Energy Potential map (Figure 5) is to provide data for an initial assessment of the annual available wind energy in any general area of the Northwest Territories. Together with the monthly maps it is possible to make an estimate as to the seasonal as well as the annual available wind energy. In practice it is necessary, of course, to verify that the area of concern has the wind-energy regime indicated by these charts. If the candidate area is near a long-term weather station, the verification is relatively simple. However, in areas with no weather records, the process requires more time and effort.

6.2.2 Qualitative Assessment

Following the initial assessment, a number of candidate sites within a general area can be identified. A general survey and qualitative assessment of these sites should be made. In forested areas, the flagging of trees is often used as an indicator of strong and persistent winds (Wade and Hewson, 1979). This, of course, has limited application in the Northwest Territories. Evidence of strong and persistent winds can be seen in the orientation and patterns of sand dunes, snowdrifts and sandblasting. Wind stress on shrubs and other vegetation should also be noted. Such qualitative evidence must be interpreted very carefully. There is danger of confusing the observed features with very strong but infrequent winds. Moderate to strong, but persistent, winds generally offer the best situations for wind exploitation.

A qualitative assessment is not complete without interviewing the long-time residents of the area of interest. If cooperative they can be very helpful in providing information useful in making qualitative judgements as to the merits of one candidate site over another.

6.2.3 Topographical Considerations

Topographical features such as valleys or ridges can have profound influences on wind patterns. Moving air is channelled by valleys and hills much like water is channelled in its streambed. Topographical effects can work to the advantage or disadvantage of the wind engineer. Judicious site selection in rolling topography can yield a significant increase in the potential energy supply. Careless siting can result in general decrease of wind energy as well as introduce turbulence that could have detrimental effects on the hardware. Several topographical effects can be noted:

1. The valley effect: The channelling effects of valleys and ridges are well known and should be carefully considered in site selction. The effect is illustrated in Figure 96.

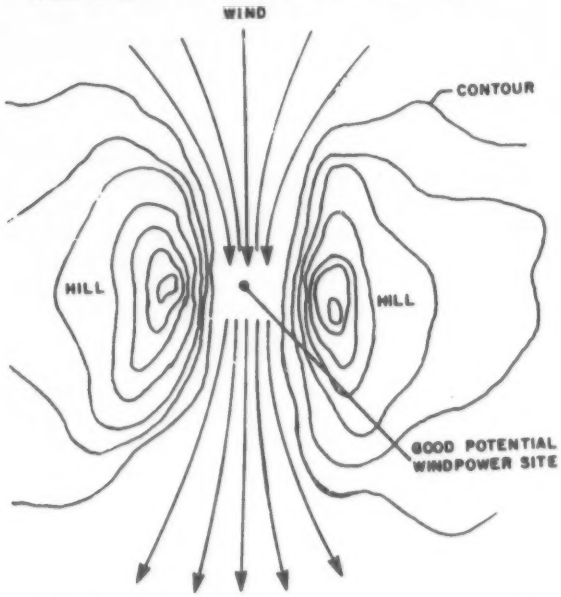


Figure 96. Ideal wind-energy site in valley (from Hawrelak et al.)

2. Ridge Effects: Numerous studies have shown that when wind encounters a long ridge with axis perpendicular to the wind direction, there is a speed-up over the crest (Figure 97). According to a report by the World Meteorological Organization (1974), the most effective structure for WECS installations is a whaleback several miles in length. Small round hills, on the other hand, do not have the speed-up effect over the crest as the wind tends to blow around them.

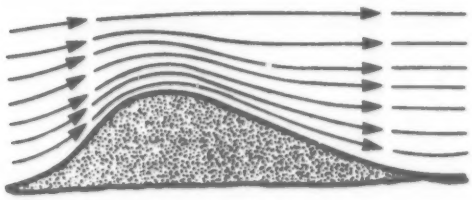


Figure 97. Acceleration effect over the crest of a hill.

In the Northwest Territories, some eskers lying perpendicular to the major axis of the energy rose would probably be excellent sites for consideration.

Sharp ridges or ridges with a steep slope on the windward side should be avoided as such structures may introduce turbulence and in some cases there may actually be a reverse flow just beyond the crest of the ridge (Figure 98).

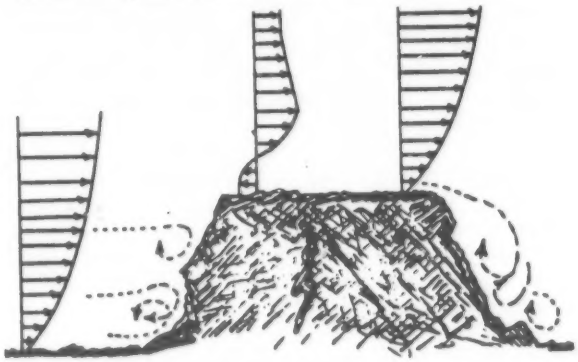


Figure 98. Possible reverse flow induced at crest of sharp ridge (from Cheremisinoff, 1978).

Wind flow over hills and other high ground can be exceedingly complex; even rather small hills can have significant down-wind effects. Under the right combinations of wind and temperature, standing waves can be generated to the lee of small hills less than 100 m above the general terrain. Under certain conditions, these waves are propogated down wind. Thus, if a WECS is located to the lee of a hill, there may be periodic lulls and gusts, often accompanied by turbulence. This phenomenon has been observed at many northern locations and is a possible explanation for the erratic winds experienced at Baker lake in winter with northwesterly winds. A site to the lee of a hill should be avoided if at all possible.

3. Coastal Effect: A coastal area can alter the wind flow much like a ridge of whaleback. The water surface provides an unobstructed area and when winds flow from the water to the land there is a speed-up as the wind rises onshore. If the shoreline has steep cliffs the effects can make the shoreline unsuitable as in the case of the ridge with a steep up-wind slope. If, however, the shoreline has a gradual slope the effects can be beneficial.

6.2.4 Wind Prospecting

Wind prospecting is essentially a search for a site with the most suitable wind regime. If the procedures outlined in the previous section have been followed, the number of candidate sites should be only two or three. The questions as to which is the best site must still be answered. Also, knowledge of the wind-energy regime at the site is necessary in order to select a suitable wind machine.

6.2.4.1 Candidate Site With Historical Wind Data

If the candidate sites are fairly close to a long-term weather station, the final site selection should be relatively simple. The candidate sites should be instrumented with self-recording anemometers or totalizing anemometers in order to compare the wind regime at each site with that of the nearby weather station.

6.2.4.2 Candidate Site Without Historical Wind Data.

For candidate sites far removed from a long-term station, the problem becomes complicated. The main problem in such a situation is to determine whether the initial assessment was reasonable. Many treatises on site selection suggest that in the absence of suitable wind records, a self-recording anemometer should be erected to obtain at least one year's wind data. These data are then "**normalized**" by means of a statistical comparison with the nearest long-term weather station. The World Meteorological Organization Technical Note No. 175 (1981) sounds a note of caution and indicates clearly that the analyst must be certain that the year in question is representative. The present authors share this concern but suggest that the definition of "**representative**" may be somewhat difficult when referring to wind regimes in the Northwest Territories. Reference to Section 5.2.2 should satisfy the reader that wind energy at any one location may vary considerably from year to year. Because of the distances involved, it is questionable whether a purely statistical comparison with the nearest long-term station has any validity. This, of course, begs the question of how to assess the potential wind energy at a candidate site without a wind record. The desirability of at least one year's wind data from a candidate site is not questioned. Such data should, however, be analysed and compared with long-term stations with reference to daily weather maps and mean monthly pressure charts.

6.2.5 The Energy Rose

The site selection is not complete without reference to the energy rose. This diagram is essentially a picture indicating the main direction or directions from which the wind energy comes. These directions should be kept free from obstacles that might impede the wind flow or introduce turbulence. The energy rose can be used to advantage with topographic maps or a knowledge of the topography to ensure that maximum benefit is obtained from the up-wind terrain.

The only known energy roses available for the Northwest Territories are those included in Chapter 5 of this report. For other locations it is possible to construct crude energy roses if wind-speed and direction data are available.

6.2.6 Some Physical Factors

Several physical factors at candidate sites must be considered:

1. Transmission distance: Transmission distance can be a serious problem for small and medium-sized installations. Line loss for a 12 V output using #4 copper wire over a distance of 30 m can amount to almost 50% of the initial output. For a 240 V transmission over the same line, the loss would be less than 1%. For larger machines with a high AC voltage, output transmission distance is not as critical and maximum advantage could be taken of optimum wind regimes — even tens of kilometres from the user location.
2. Logistics: The logistics of tower anchoring and guying, and the lifting of a heavy generator to the top of the tower must be carefully considered before selecting a final site. Improperly anchored towers have blown over in the Northwest Territories. Large machines with heavy generators may have serious problems relating to permafrost.

6.2.7 Hazard Evaluation

Natural and man-caused hazards must be evaluated in any site selection. Perhaps the greatest hazard associated with any wind installation is that of extreme winds. The structure must be designed to withstand the maximum probable wind at that location. Maximum recorded wind speeds for selected stations (for the analysis period) are included in Table 4. Maximum computed gust speeds are included in the Canadian Normals (Environment Canada, 1975).

Other natural hazards include obstructions up wind which may induce turbulence and thus damage or shorten the life of the machine. Rotor icing can be a problem at coastal locations just before freeze-up.

6.3 TERRAIN ENHANCEMENT

Some engineers suggest actually modifying the terrain up wind from a WECS to conform with the ideal features to artificially increase the wind speed at the WEC site. A typical approach is to modify the terrain in a valley with gently sloping sides as suggested by Eldridge (Figure 99).

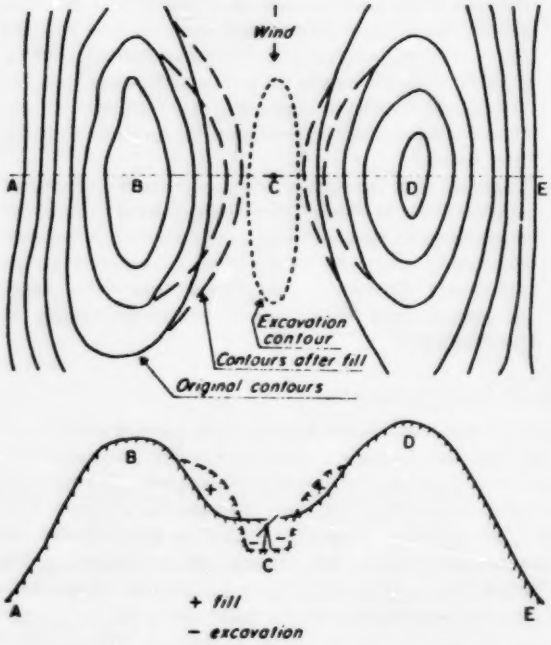


Figure 99. Terrain enhancement as suggested by Eldridge (1975).

Such modifications would, of course, find limited application in the Northwest Territories, especially in eastern areas. The idea is not as impractical as it may first appear. In the northwest Territories there is one commodity — snow — which can be manipulated to create artificial valleys and hills. The judicious placing of snow fences up wind and to either side of WECS might well have an effect similar to the terrain enhancement suggested by Eldridge.

7. Conclusions

7. CONCLUSIONS

1. A significant portion of the Northwest Territories has a good to very good wind-energy potential. The Keewatin along the west coast of Hudson Bay has a potential as good as some of the most favourable sites elsewhere on this continent.

2. Unfortunately, the poorest potential coincides with the larger population centres of the western Northwest Territories. Most of the Mackenzie Valley and the Great Slave Lake area is unsuited to a wind-energy program for normal domestic or commercial applications.

3. In the eastern Northwest Territories, the wind records are representative only of the immediate environment of the weather station. The communities are in sheltered locations and, although wind-energy potential may be good at a nearby location, transmission difficulties may limit many wind-energy applications or make them very expensive.

4. Potential wind energy shows significant year-to-year variations at most windy locations in the Northwest Territories. Potential energy for a particular year can differ from the long-term average by a factor of 1.5 to 2. Such variations, although not peculiar to the Northwest Territories, appear to be more pronounced in the north.

5. The year-to-year variations imply that storage of energy and auxiliary energy sources are mandatory for all domestic and commercial applications of wind-energy conversion systems. Even the areas with good wind-energy potential have at least one seven to 10 day period in 10 years where significant energy production is not possible due to light winds. Most sites have about 10 periods per year lasting up to 24 consecutive hours where there is no energy production. In the Mackenzie Valley, the periods of no energy production can last two to three weeks.

6. Actual site selection is critical and may affect the success or failure of a WECS installation. For sites at or near stations with long-term weather records, the site selection process should present little difficulty and should be relatively inexpensive. In remote areas without convenient weather records, site selection may be complicated and costly — especially for large installations. The traditional statistical approach of generating synthetic wind regimes by comparing a short-term record at the remote site with long-term records of the nearest weather station may be very misleading in the Northwest Territories.

7. The conclusions of this report refer to wind regimes at a height of 10m — the level of interest for smaller domestic or commercial applications. General wind-energy patterns at 30 to 50 m, the levels of interest for large industrial or utility applications, should be similar.

8. Generally speaking, the lee of hills, even only 50 to 100 m in height, should be avoided as sites for WECS due to the possibility of severe low level turbulence under certain conditions of atmospheric stability.

9. The harsh environment of the Northwest Territories introduces logistical problems relating to installation and operation of WECS. These logistical problems may have significant bearing on the success or failures of wind-energy programs in the Northwest Territories.

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8. Appendix

8.1 GLOSSARY OF ENERGY-RELATED TERMS

AC – alternating current.

Cut-in speed – the wind speed at which an aerogenerator is activated as the wind speed increases.

Cut-off speed – the wind speed at which the wind machine is designed to shut off to prevent damage from high winds (often referred to as the furling speed).

DC – direct current.

Energy Rose – pattern formed by a diagram illustrating vectors representing potential wind energy.

Power – the rate at which energy is consumed.

Rated output capacity – output power of an aerogenerator that is operating at constant output corresponding to the rated wind speed.

Rated wind speed – the lowest wind speed for which the rated power output of a wind collector is manufactured.

Terrain enhancement – the artificial modification of the terrain up wind from a wind machine to augment the available wind-energy.

WECS – Wind-Energy Conversion System.

Wind prospecting – searching for a site with the most suitable wind regime for a particular wind machine.

Windrun – the total number of kilometres of wind that passes a point during a specified period of time.

Wind speed – **hourly:** the wind speed averaged over the minute just prior to the hour.

Daily Mean: the total daily windrun divided by 24.

Monthly Mean: the total windrun for the month divided by the number of hours in that month.

Annual Mean: the mean of the monthly wind speeds.

8.2 WIND AND WIND-ENERGY SUMMARIES

8.2.1 Table 2

This table summarizes wind speeds by month and year over the available period of record for stations in the Northwest Territories. Stations near latitude 60 (but outside the Northwest Territories) were included if such stations contributed to a better understanding of the wind energy patterns in the Northwest Territories.

These data were used to compute the monthly and annual wind energy in Chapter 4.

8.2.2 Table 3

This table lists the mean annual wind energy for winds between 10 and 58 km/h as computed by Lamont's method. In addition, a qualitative assessment of the representativeness of the site is included.

8.2.3 Table 4

This table summarizes the raw data used in the computation of the graphs in Chapter 5. For each station, four parameters are listed:

1. Mean monthly and mean annual wind speed (over the analysis period). This makes comparison easier with the long-term records summarized in Table 2.

2. Mean monthly and annual potential wind energy during the analysis period.

3. The recorded mean and annual potential wind energy for each month and year of the analysis period. These values were obtained by a rigorous solution of the energy equation (Chapter 2).

4. The maximum observed wind speed in the analysis period. This information is required for tower design. Maxwell (1981) and Environment Canada (1975) provide more complete data on maximum wind speeds and computed gust speeds.

Table 2: Wind-speed summaries for stations in the Northwest Territories with published wind data (wind speeds in km/H).

	Period of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Data Source
Western N.W.T.	western														
Contwoyto Lake	1957-76	18.6	14.9	15.4	15.7	17.4	16.2	15.7	19.0	22.9	22.4	17.3	16.3	17.6	Proj # 1124
Fort Good Hope	1955-72	8.6	7.7	9.1	10.7	12.2	12.3	11.4	11.7	11.5	10.6	7.7	7.2	10.1	Canadian Normals
Fort Reliance	1953-76	11.0	9.0	9.9	11.5	11.7	11.0	10.7	11.8	14.4	15.8	13.1	10.9	11.7	Proj # 1124
Fort Resolution	1955-70	14.9	13.3	14.1	15.8	15.2	15.0	14.4	14.7	15.8	17.1	16.6	14.6	15.2	Canadian Normals
Fort Simpson (A)	1955-63	9.6	10.6	11.2	12.3	11.8	10.9	10.7	10.4	11.7	11.4	11.8	10.4	11.0	Proj # 1124
Fort Smith (A)	1955-72	11.7	11.8	12.2	13.6	13.8	13.0	12.3	12.2	13.1	13.4	12.3	11.2	12.5	Canadian Normals
Hay River (A)	1955-72	10.4	9.9	10.4	11.8	11.8	11.5	11.4	11.7	13.0	13.0	12.6	10.4	11.5	Canadian Normals
Inuvik (A)	1959-76	7.4	7.0	9.3	10.6	12.3	13.1	12.2	11.7	10.9	10.1	7.4	7.2	9.9	Proj # 1124
Norman Wells (A)	1955-72	11.2	10.1	11.8	13.3	13.4	14.6	13.1	13.0	13.3	13.0	10.7	10.1	12.3	Canadian Normals
Port Radium	1953-74	10.4	8.3	10.2	12.0	13.0	11.7	10.1	13.0	15.5	16.5	14.1	10.6	12.1	Proj # 1124
Sachs Harbour	1955-70	18.6	17.9	18.6	20.8	20.6	20.8	21.0	21.6	23.4	24.2	20.2	20.0	20.6	Canadian Normals
Snare Rapids	1956-65	7.5	7.0	9.3	11.4	11.4	13.2	11.2	11.0	10.6	10.9	9.0	7.7	9.9	Proj # 1124
Wrigley (A)	1957-72	11.0	11.5	12.6	13.6	12.3	11.7	10.9	10.9	10.9	11.2	9.8	10.4	11.4	Canadian Normals
Yellowknife (A)	1955-72	14.2	13.8	14.9	17.0	17.3	17.6	16.6	16.2	17.4	17.3	15.7	13.6	16.0	Canadian Normals
Arctic Coast															
Byron Bay	1953-76	26.2	23.5	21.6	21.1	20.0	21.6	18.2	20.0	22.2	22.2	20.5	21.4	21.6	Proj # 1124
Cambridge Bay (A)	1955-72	21.6	19.7	18.9	19.4	20.0	20.6	20.0	21.1	22.7	23.0	19.8	18.9	20.5	Canadian Normals
Cape Parry (A)	1959-73	18.9	17.1	19.0	19.8	19.2	21.0	18.9	19.4	20.3	22.2	19.5	19.5	19.5	Proj # 1124
Cape Young	1974-76	16.5	17.1	15.0	13.1	16.3	13.3	13.3	16.3	16.2	17.9	17.9	17.0	15.8	Proj # 1124
Clinton Point	1950-76	26.7	17.9	17.9	16.3	17.0	15.2	16.6	18.1	20.3	21.9	19.5	20.0	19.0	Proj # 1124
Coppermine	1953-76	20.5	16.8	15.7	13.6	14.4	13.3	14.7	16.8	18.1	19.4	17.8	16.8	16.5	Proj # 1124
Gladman Point	1976-79	16.5	12.3	16.8	19.7	19.4	19.0	18.6	20.0	18.1	15.5	15.7	14.2	17.1	Proj # 2302340
Hall Beach (A)	1958-72	21.6	24.0	21.4	20.6	21.3	19.0	17.3	19.4	25.0	25.4	23.5	20.5	21.6	Canadian Normals
Holman Island	1953-67	12.6	13.9	15.2	12.3	12.3	17.8	13.6	15.9	19.5	22.2	16.6	16.3	16.5	Proj # 1124
Jenny Lind Island	1973-79	16.8	17.3	17.8	17.4	18.1	18.5	17.8	16.8	21.8	20.2	14.4	12.6	17.4	Proj # 2302650
Lady Franklin	1953-76	25.1	24.0	20.0	20.6	24.6	21.6	20.0	22.4	24.2	24.6	22.7	21.3	22.6	Proj # 1124
Longstaff Bluff	1976-79	19.8	13.9	19.2	18.1	18.5	18.5	18.1	16.8	18.1	18.6	14.7	19.4	17.8	Proj # 2402684
Mackar Inlet	1955-72	12.2	10.5	9.8	12.2	12.4	11.6	10.3	11.4	15.0	15.6	13.8	11.3	11.3	Maxwell 1980
Nicholson Point	1974-76	16.6	15.7	16.2	15.7	20.5	17.1	17.6	20.6	19.2	17.1	14.7	12.5	17.0	Proj # 1124
Pelly Bay	1955-72	19.1	19.3	17.7	16.4	16.7	15.0	14.0	14.6	18.5	19.0	17.7	18.3	17.2	Maxwell 1980
Shepherds Bay	1973-76	14.2	12.2	11.8	16.6	17.1	17.4	18.7	18.2	18.7	17.0	14.6	15.2	16.0	Proj # 2303685
Tuktoyaktuk (A)	1974-76	20.6	16.0	15.8	17.3	17.3	18.1	18.2	18.6	20.3	19.0	16.3	15.2	17.4	Proj # 1124

Table 2 concluded

	Period of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Data Source
Keewatin															
Baker Lake	1963-72	25.9	26.6	23.8	22.6	22.6	21.0	19.4	18.9	21.8	23.2	22.6	21.4	22.4	Canadian Normals
Chesterfield	1963-68	22.7	26.2	22.7	21.4	20.8	18.6	16.0	20.3	25.3	27.8	25.8	22.9	22.6	Canadian Normals
Coral Harbour	1955-72	20.5	21.1	17.6	19.5	19.4	20.0	18.4	20.0	21.6	21.9	23.2	21.1	20.5	Canadian Normals
Ennadai Lake	1953-76	22.7	21.8	22.2	24.6	24.3	23.4	22.2	23.2	26.2	26.7	23.2	21.3	23.5	Proj # 1124
Eastern N.W.T.															
Arctic Bay	1953-76	6.2	5.8	4.0	6.4	9.4	11.7	11.5	10.7	9.6	9.6	5.8	5.0	8.0	Proj # 1124
Brevoort Island	1960-72	21.9	20.9	20.0	19.5	17.2	14.0	14.5	14.8	17.1	20.9	21.1	20.9	18.6	Maxwell 1980
Broughton Island	1956-72	11.1	9.7	7.9	8.8	9.2	8.0	7.1	7.7	10.0	9.5	8.5	9.0	8.9	Maxwell 1980
Cape Dyer (A)	1959-72	17.9	15.2	12.5	12.9	14.1	12.5	11.0	11.5	15.4	16.8	14.9	16.2	14.2	Canadian Normals
Cape Hooper	1956-72	18.2	15.9	16.6	17.1	15.6	14.8	13.0	13.2	19.1	21.9	19.8	17.4	16.9	Maxwell 1980
Cape Hopes Advance PO	1955-71	26.2	28.6	25.8	25.9	25.8	23.2	22.9	25.4	31.8	32.2	33.1	31.4	27.6	Canadian Normals
Clyde	1953-76	8.6	9.8	7.2	7.8	10.6	10.6	9.4	10.2	12.6	15.0	11.7	9.0	10.2	Proj # 1124
Dewar Lakes	1956-72	18.8	17.2	16.6	17.9	20.6	19.1	20.4	20.6	18.8	17.7	18.2	15.1	18.4	Maxwell 1980
Frobisher Bay (A)	1955-72	15.5	15.5	14.0	17.0	20.0	17.1	13.3	13.6	17.8	20.0	18.2	16.5	16.5	Canadian Normals
Nottingham Island	1956-70	14.4	17.3	15.2	10.9	20.0	18.1	16.2	17.9	17.4	21.4	20.2	17.3	17.9	Canadian Normals
Pond Inlet	1957-76	10.6	9.0	9.0	7.5	8.2	7.4	8.0	8.8	12.0	13.3	8.6	10.1	9.4	Proj # 1124
Resolution Island	1962-72	41.1	41.1	38.7	24.4	31.0	32.5	27.8	30.9	35.2	36.5	35.8	39.8	35.4	Canadian Normals
Rowley Island	1960-70	15.4	16.1	13.8	13.8	15.6	15.0	16.3	16.3	18.8	19.0	17.2	13.4	15.9	Maxwell 1980
Queen Elizabeth Is.															
Alert	1955-72	9.6	9.3	7.4	7.8	9.0	10.6	12.3	10.7	10.6	11.2	8.8	9.3	9.8	Canadian Normals
Coburg Island	1972-74	10.4	12.6	13.8	9.1	14.9	18.2	16.0	12.6	16.2	13.4	11.8	14.4	13.4	Proj # 1124
Devon Island	1961-62	5.4	5.3	3.0	3.5	9.9	7.4	6.6	10.2	9.3	9.3	6.7	7.0	7.0	Proj # 1124
Eureka	1955-72	10.4	9.3	8.5	9.6	13.2	17.0	17.4	14.4	11.5	9.6	8.6	8.5	11.5	Canadian Normals
Isachsen	1955-72	17.1	15.0	13.6	12.5	17.3	19.5	17.1	17.3	16.8	14.4	13.0	14.9	15.7	Canadian Normals
Johnson Point	1972-75	19.0	18.2	16.0	20.0	20.8	17.9	16.3	16.2	16.6	19.4	19.2	17.9	18.1	Proj # 1124
Mould Bay	1953-76	15.5	13.1	12.5	11.8	15.0	17.4	18.1	17.1	17.4	15.7	14.2	14.6	15.2	Proj # 1124
Rea Point	1970-76	20.3	21.9	20.2	16.0	18.7	19.2	19.5	20.2	21.9	21.1	20.6	20.0	20.0	Proj # 1124
Resolute (A)	1953-76	21.4	21.1	20.0	19.0	21.0	21.8	20.3	21.6	24.3	24.5	20.8	20.3	21.3	Proj # 1124

Station	Mean annual wind energy kwh/m²	Qualitative assessment of data	Reason for assessment
Western N.W.T.			
Contwoyto Lake	900		
Fort Good Hope	300		
Fort Reliance	300	too low	general area sheltered
Fort Resolution	630		
Fort Simpson (A)	200		
Fort Smith (A)	340		
Hay River (A)	300		
Inuvik (A)	220	likely too low	sheltered location
Norman Wells (A)	490		
Port Radium	380	likely too low	sheltered location
Sachs Harbour	1340		
Snare Rapids	300		
Wrigley (A)	300		
Yellowknife (A)	640		
Arctic Coast			
Byron Bay	1470		
Cambridge Bay (A)	1340		
Cape Parry (A)	1230		
Cape Young	680	too low	sheltered location
Clinton Point	1080		
Coppermine	780	too low	sheltered location
Gladman Point	820		
Hall Beach (A)	1400		
Holman Island	780	too low	sheltered location
Jenny Lind Island	900		
Lady Franklin	1630		
Longstaff Bluff	980		
Mecker Inlet	300	too low	sheltered location
Nicholson Point	840		
Pelly Bay	900		
Shepherds Bay	840		
Tuktoyaktuk (A)	900		

Station	Mean annual wind energy kwh/m²	Qualitative assessment of data	Reason for assessment
Keewatin			
Baker Lake	1680		
Chesterfield	1580		
Coral Harbour	1300		
Ennadai Lake	1740	too high	anemometer on esker
Eastern Arctic			
Arctic Bay	300	too low	sheltered location
Brevoort Island	1020	likely too low	
Broughton Island	300	too low	sheltered fiord
Cape Dyer (A)	870	too low	sheltered location
Cape Hooper	780		
Cape Hopes Advance	2340	too high	local wind
P.O.			acceleration
Clyde	300	too low	sheltered
Dewar Lakes	990		
Frobisher Bay (A)	1080		
Nottingham Island	960	too low	sheltered
Pond Inlet	300	too low	sheltered location
Resolution Island	3390	too high	anemometer on hill
Rowley Island	640	likely too low	
Queen Elizabeth Islands			
Alert	300		
Coburg Island	460		
Devon Island	300		
Eureka	300		
Isacheen	680		
Johnson Point	980		
Mould Bay	680		
Rea Point	1280		
Resolute (A)	1680	likely too high	local wind acceleration

Table: 3 Mean annual wind energy (winds 10-88 km/h) for stations in the Northwest Territories with published wind data. (computed with data from Table 2 using Lamont's method).

Table 4: Wind-speed and wind-energy summaries for selected stations in the Northwest Territories.

FORT SIMPSON A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 61°45'N
LONGITUDE: 121°14'W
ELEVATION: 176 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	7.7	8.6	9.5	10.5	10.3	9.3	8.5	8.4	8.6	8.6	8.0	8.4	8.7
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	52.6	46.3	56.7	61.5	56.0	41.2	38.2	38.8	41.2	44.8	41.6	31.4	550.3
RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)													
YEAR: 1967	16.4	49.8	71.8	78.3	69.8	61.8	30.6	48.1	46.1	37.0	60.1	38.4	610.5
1968	64.4	48.4	56.1	63.0	59.5	32.1	25.1	28.6	55.9	38.4	42.0	38.4	553.0
1969	21.3	39.0	62.6	55.6	51.8	35.8	55.1	37.4	21.4	31.2	67.8	16.8	496.1
1970	76.1	49.6	77.4	69.1	46.1	46.3	40.8	38.6	74.3	44.3	43.1	22.1	626.0
1971	52.6	46.8	49.9	56.2	54.8	28.4	33.3	29.4	48.5	60.4	30.1	38.0	529.3
1972	64.1	51.9	63.8	63.7	63.8	42.4	38.7	23.3	25.9	49.6	21.1	26.8	536.0
1973	69.0	27.3	62.9	66.1	36.8	42.9	43.4	62.3	33.2	35.8	51.1	34.3	565.2
1974	77.3	63.9	43.2	64.2	51.9	40.3	54.1	32.4	35.0	76.0	26.1	31.6	595.8
1975	38.7	35.5	32.3	61.0	57.0	27.8	32.4	47.9	31.7	40.5	38.4	22.7	465.9
1976	45.8	66.7	47.0	36.5	68.6	52.6	27.3	38.5	38.6	34.9	36.6	44.1	539.2

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 66 km/h, AND OCCURED FOR 1 HOURS.

FORT SMITH A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1955, TO DEC 1972.

LATITUDE: 60° 1'N
LONGITUDE: 111°58'W
ELEVATION: 203 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	11.8	11.8	12.2	13.6	13.8	12.8	12.3	12.2	13.1	13.5	12.3	11.2	12.5
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	96.3	79.5	92.2	109.4	103.4	88.2	78.9	78.1	97.0	113.1	90.6	83.9	1110.6
RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)													
YEAR: 1955	45.2	112.8	89.9	99.7	111.6	102.9	80.3	78.0	99.2	100.4	90.4	96.9	1107.3
1956	76.8	59.9	106.6	139.0	89.6	93.4	62.0	77.7	70.6	138.6	124.3	72.6	1110.7
1957	111.2	126.7	56.2	63.5	92.7	78.5	73.5	47.0	151.6	117.8	114.9	76.5	1109.9
1958	93.5	52.8	48.7	73.0	86.7	72.1	64.1	63.7	71.6	92.7	61.5	77.8	858.3
1959	202.9	71.1	129.3	114.6	88.9	96.2	82.5	52.8	122.6	152.3	110.6	125.5	1349.3

1960	69.9	62.2	83.7	123.6	85.1	85.1	74.8	73.3	102.2	112.4	63.5	72.3	1008.5
1961	77.8	77.9	72.2	148.7	93.3	93.6	111.1	73.8	104.6	119.7	109.6	82.9	1165.1
1962	131.0	52.5	63.5	86.2	68.1	53.7	84.1	69.7	87.4	71.1	65.9	70.8	914.1
1963	139.7	55.1	52.3	93.6	85.9	84.6	61.4	53.4	80.6	69.4	79.2	85.2	960.2
1964	69.2	104.4	139.2	136.8	90.4	85.9	68.6	83.7	69.4	111.9	109.5	63.4	1144.4
1965	103.4	84.7	136.3	153.5	112.2	149.8	67.1	65.9	81.0	111.0	62.9	47.6	1175.5
1966	77.4	102.0	114.7	100.2	189.8	55.7	80.5	120.0	85.2	126.4	82.1	38.6	1172.6
1967	34.8	49.2	47.8	48.6	79.0	76.9	55.8	78.6	142.9	116.7	128.6	146.1	1005.0
1968	68.7	89.4	115.2	125.3	107.5	111.6	83.7	95.7	94.5	106.2	113.2	108.5	1219.4
1969	50.5	85.3	99.5	91.1	104.6	70.7	89.6	102.2	62.9	66.8	133.8	121.1	1078.0
1970	118.9	93.9	117.3	83.1	120.7	126.6	91.4	95.4	103.8	110.0	59.2	85.9	1206.1
1971	146.1	79.1	90.1	133.2	140.8	89.1	85.4	94.0	143.5	150.5	61.4	94.0	1287.3
1972	117.4	123.1	96.4	153.2	104.8	80.3	85.2	70.8	73.3	161.1	89.6	44.0	1169.0

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 87 km/h, AND OCCURED FOR 1 HOURS.

HAY RIVER A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 60°51'N
LONGITUDE: 115°46'W
ELEVATION: 161 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	12.0	10.9	11.6	13.3	13.4	13.3	12.2	12.5	13.6	13.3	13.6	11.8	12.6
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	106.0	77.5	91.9	109.9	111.2	102.2	84.6	93.3	122.5	123.0	113.6	93.6	1232.4

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1967	31.0	46.7	50.1	50.9	63.7	66.0	53.6	79.5	99.2	79.9	84.6	85.9	603.3
1968	69.9	34.9	59.6	70.6	96.8	64.0	53.3	46.0	46.7	81.5	67.1	43.3	639.8
1969	33.7	26.4	36.5	113.8	46.4	63.1	61.5	70.4	67.6	47.0	113.1	32.5	751.1
1970	61.5	36.9	57.1	64.6	86.9	79.9	66.8	73.3	93.4	84.5	74.5	67.7	819.1
1971	123.3	85.1	107.5	137.9	131.2	101.9	91.3	95.0	260.4	177.9	132.1	116.4	1939.6
1972	139.1	136.0	109.0	169.1	131.2	136.6	86.4	89.4	199.5	276.5	131.7	188.2	1786.5
1973	186.4	123.5	169.2	184.1	211.9	165.4	107.6	208.5	186.0	163.1	146.1	123.6	1884.7
1974	247.2	157.4	145.2	111.9	148.7	156.3	126.2	113.5	63.3	127.1	116.5	102.5	1610.6
1975	108.2	46.3	83.3	67.0	71.3	58.8	84.4	61.3	72.4	73.7	87.9	72.5	886.1
1976	84.5	116.2	104.4	126.1	166.4	126.3	120.7	96.0	137.7	179.0	171.1	114.3	1543.7

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 69 km/h, AND OCCURED FOR 1 HOURS.

Table 4 continued.

INUVIK A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 68° 18'N
LONGITUDE: 133° 29'W
ELEVATION: 61 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	7.7	7.4	9.3	10.6	12.8	13.5	12.5	12.1	10.7	10.3	7.5	6.8	10.1
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	58.3	39.5	53.4	62.2	88.9	87.8	77.4	78.1	59.8	61.4	40.5	40.1	748.6

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	53.7	38.6	56.3	57.3	101.1	83.3	59.2	61.6	49.3	46.6	33.2	27.2	686.4
	1968	58.4	33.7	36.6	48.8	82.8	78.6	85.0	50.8	36.0	36.5	3.8	54.3	606.6
	1969	34.0	13.4	46.4	66.6	61.1	86.7	86.6	133.7	62.2	36.0	20.2	19.7	682.5
	1970	34.5	31.8	70.5	80.8	86.4	83.5	80.1	68.0	76.3	68.4	85.5	16.3	783.1
	1971	66.3	31.4	40.5	56.3	62.5	110.5	82.6	109.4	60.6	61.3	46.3	89.9	790.0
	1972	56.0	66.6	86.6	83.1	80.4	78.4	67.7	80.6	89.7	48.1	26.7	61.6	824.7
	1973	50.2	43.1	33.3	37.7	56.0	89.4	63.7	65.0	26.4	66.9	46.9	31.6	576.3
	1974	146.3	16.7	32.6	40.6	64.7	103.6	66.6	76.4	63.9	73.2	43.2	34.6	748.7
	1975	47.6	60.6	66.2	66.2	121.6	106.1	106.1	84.2	76.2	103.3	46.7	42.1	901.3
	1976	36.5	63.6	46.6	66.6	110.6	76.4	66.7	82.7	63.9	67.1	46.7	36.2	748.6

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 61 km/h, AND OCCURED FOR 1 HOURS.

NORMAN WELLS A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 65° 17'N
LONGITUDE: 126° 48'W
ELEVATION: 64 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	11.2	9.8	12.0	12.4	13.2	14.8	13.6	13.3	13.6	13.6	10.7	9.2	12.3
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	166.7	112.2	168.1	132.1	121.7	141.2	126.8	122.3	126.5	156.6	125.5	118.5	1640.2

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	46.1	77.8	177.3	123.0	116.0	206.8	84.1	100.0	84.8	149.2	116.1	131.4	1416.6
	1968	234.0	75.6	268.3	120.7	165.5	120.5	164.0	125.0	117.2	177.6	141.6	233.1	1843.9
	1969	148.4	36.5	166.6	270.9	133.1	176.0	211.5	217.3	164.3	89.1	159.5	38.2	1840.4
	1970	166.5	116.9	330.8	122.7	150.5	177.5	145.5	118.0	216.5	170.3	202.8	59.1	1980.3
	1971	230.1	70.6	214.1	140.4	118.9	131.9	82.4	136.5	112.9	174.5	116.7	175.3	1716.2

1972	280.3	366.6	124.8	110.5	121.3	122.6	83.1	46.3	143.8	88.1	47.3	139.1	1664.7
1973	108.4	137.7	73.0	93.3	83.4	107.5	88.0	120.2	60.5	146.2	160.9	180.0	1371.2
1974	403.3	71.0	161.5	110.4	113.6	168.8	134.8	137.3	109.9	236.2	117.7	83.4	1848.2
1975	93.0	118.2	76.3	123.9	73.2	71.6	71.2	104.4	85.9	156.5	88.0	41.0	1073.3
1976	133.0	84.7	89.1	106.5	139.3	128.9	182.3	116.2	149.1	177.0	133.9	113.2	1561.1

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 66 km/h, AND OCCURED FOR 1 HOURS.

YELLOWKNIFE A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 62° 28'N
LONGITUDE: 114° 27'W
ELEVATION: 206 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	13.4	13.8	14.5	16.0	16.6	16.5	15.8	15.4	15.9	16.2	14.7	12.6	15.1
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	132.4	117.3	148.2	163.2	179.5	172.3	151.4	146.8	156.5	182.6	138.2	110.4	1789.0

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	72.6	101.4	152.1	138.7	194.8	226.4	172.9	169.5	191.6	162.2	171.9	215.3	1969.3
	1968	96.9	124.2	152.5	144.2	189.1	212.7	201.5	229.9	183.2	215.6	174.7	119.4	2043.8
	1969	124.2	118.1	120.3	169.1	142.9	190.5	169.3	167.0	123.3	122.8	204.7	127.1	1819.3
	1970	194.3	118.6	170.5	136.2	175.8	191.6	134.6	126.5	170.6	142.5	97.2	88.9	1746.1
	1971	181.6	114.3	160.9	157.6	246.7	128.1	133.0	136.4	235.8	220.4	107.8	86.0	1909.6
	1972	140.3	170.8	125.7	204.1	192.5	162.4	111.7	98.2	144.4	201.8	131.1	70.0	1832.9
	1973	109.0	107.1	166.6	187.9	185.6	193.4	175.1	210.9	152.6	165.0	146.7	109.9	1918.8
	1974	203.8	142.7	197.1	175.8	178.0	193.0	188.0	132.2	166.8	303.7	127.8	135.0	2143.9
	1975	112.3	127.6	156.6	104.1	147.8	105.8	103.5	118.7	113.8	117.5	94.1	61.6	1363.3
	1976	89.0	89.8	80.2	96.4	151.8	118.5	104.9	78.3	83.0	174.1	127.6	90.1	1282.7

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 64 km/h, AND OCCURED FOR 1 HOURS.

Table 4 concluded.

HALL BEACH A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 68° 47'N
LONGITUDE: 81° 15'W
ELEVATION: 7 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	23.1	25.2	23.6	22.5	22.4	19.2	18.1	20.1	25.7	27.3	25.2	21.8	22.8
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	572.2	628.4	648.8	471.3	490.2	312.9	258.0	365.2	725.8	905.5	718.2	499.5	6597.3
RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)													
YEAR: 1967	386.8	498.8	879.9	683.6	352.1	398.7	217.1	397.8	1120.0	559.2	663.4	167.5	6327.9
1968	442.7	827.1	451.2	376.8	660.5	260.5	293.6	325.0	758.8	546.9	934.6	598.6	6477.3
1969	474.0	516.8	570.7	294.8	615.9	290.9	195.2	188.9	535.8	1094.4	1189.6	306.9	6273.9
1970	493.1	585.2	497.4	392.1	339.9	716.3	242.8	316.8	889.2	1086.0	998.6	617.6	7175.0
1971	586.4	501.0	210.9	420.7	851.6	78.8	119.8	386.0	600.4	856.2	602.9	236.2	5450.8
1972	247.6	612.2	325.0	488.9	322.9	226.6	209.3	354.6	341.7	1198.7	451.2	354.8	5133.6
1973	796.6	564.2	638.1	546.6	624.9	199.2	351.9	330.4	640.6	949.8	741.3	395.7	6779.3
1974	439.1	689.8	1023.6	688.8	437.8	371.2	241.2	205.8	402.6	789.9	394.5	444.6	6129.0
1975	458.5	564.9	491.7	510.3	222.4	226.5	384.5	575.0	1526.7	1735.6	604.8	1258.6	8389.5
1976	1394.8	1125.1	1410.3	480.3	473.7	360.6	324.8	571.6	441.6	237.7	600.5	618.1	8039.2

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 106 km/h, AND OCCURED FOR 1 HOURS.

BAKER LAKE, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 64° 18'N
LONGITUDE: 96° 0'W
ELEVATION: 12 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	23.3	25.6	23.8	21.3	21.6	19.2	18.7	18.7	21.6	22.1	22.8	21.1	21.6
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	825.9	990.5	839.8	550.9	459.1	361.1	294.7	296.4	401.9	497.9	721.3	640.8	6880.3
RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)													
YEAR: 1967	578.2	617.5	837.8	711.2	594.4	479.4	425.8	448.5	620.8	649.2	621.3	1502.1	8086.4
1968	825.8	1774.2	1438.1	777.9	482.0	309.0	446.1	408.8	311.6	400.5	783.4	873.6	8831.0
1969	1268.5	673.3	1046.4	732.4	993.8	770.9	392.3	181.8	338.5	598.7	1530.5	691.3	9218.2
1970	1303.2	2611.2	1871.1	585.7	397.3	894.7	339.0	435.8	374.4	612.6	518.6	237.2	10180.8

1971	1441.2	858.1	302.7	588.8	364.1	275.3	243.2	241.3	401.5	355.7	364.9	444.1	5880.8
1972	487.5	1091.3	418.6	612.4	419.4	270.6	309.9	211.6	346.2	477.1	434.3	380.5	5459.4
1973	492.0	648.0	791.1	457.6	443.6	207.7	177.2	280.2	615.2	348.0	571.6	191.0	5233.3
1974	220.5	362.3	300.3	318.9	198.1	143.0	99.4	83.2	216.0	714.7	398.4	289.4	3344.0
1975	486.4	875.5	782.4	224.6	292.9	134.6	279.3	268.8	313.6	437.7	918.7	723.7	5738.2
1976	1155.7	729.1	609.2	499.0	405.6	125.9	234.3	393.9	480.9	384.1	1071.3	1088.8	7177.7

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 121 km/h, AND OCCURED FOR 1 HOURS.

CAMBRIDGE BAY A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 69° 6'N
LONGITUDE: 105° 7'W
ELEVATION: 23 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	23.4	22.7	22.3	21.0	22.4	22.2	22.3	23.9	27.3	26.5	23.1	21.7	23.2
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	764.6	590.1	574.8	515.6	522.7	482.3	450.3	554.4	831.5	863.5	608.2	578.5	7336.5

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
1967	203.3	327.8	546.6	320.4	445.8	224.3	355.1	389.1	440.5	545.6	155.7	356.2	4310.3
1968	276.9	443.6	579.2	285.7	294.6	248.2	411.2	432.8	722.7	519.6	685.9	505.7	5406.1
1969	376.0	325.4	363.3	588.3	524.5	479.5	348.4	355.1	442.7	904.5	638.0	302.0	5647.7
1970	658.9	634.4	676.3	590.9	382.9	571.5	361.6	543.4	1033.5	585.1	525.6	470.4	7034.6
1971	1655.1	378.9	444.1	736.7	478.9	457.8	510.2	759.1	608.9	775.4	517.5	477.3	7799.7
1972	804.6	730.3	501.5	518.1	491.1	518.1	490.6	484.4	822.6	773.7	634.0	473.9	7242.8
1973	609.9	708.8	620.0	350.1	729.4	535.0	429.9	550.0	732.8	727.9	303.5	564.7	6861.9
1974	812.8	424.9	665.1	592.5	511.1	722.0	648.6	529.0	1540.6	1916.9	497.9	435.7	9297.2
1975	1198.5	921.0	547.3	498.1	640.6	535.3	604.0	493.1	1020.3	900.9	1211.0	1092.1	9662.4
1976	1050.1	1197.5	804.4	675.4	728.3	530.8	342.9	1007.2	949.7	884.7	912.3	1123.8	10307.1

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 101 km/h, AND OCCURED FOR 1 HOURS.

CAPE PARRY A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 70° 10'N
LONGITUDE: 124° 41'W
ELEVATION: 16 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	19.4	15.9	18.4	19.7	20.1	19.9	17.2	19.5	20.1	21.8	20.2	18.9	19.3
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	435.5	269.3	392.7	469.9	397.3	317.8	218.0	307.7	352.9	475.6	423.6	387.3	4447.5

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	214.5	130.8	282.6	167.5	230.4	266.4	98.7	159.8	236.2	296.0	275.9	406.7	2765.5
	1968	302.9	256.9	318.1	306.1	249.2	287.0	257.5	328.9	300.9	682.8	526.1	314.7	4131.1
	1969	257.9	424.0	263.8	729.0	320.4	227.3	187.1	394.6	233.1	407.2	485.6	688.2	4618.0
	1970	303.2	146.8	578.8	1192.2	295.3	180.6	398.4	298.3	579.5	574.5	333.2	379.0	5259.9
	1971	519.5	165.6	458.5	591.3	293.2	337.9	192.2	337.0	334.7	369.2	589.0	202.1	4390.3
	1972	299.3	309.6	464.6	518.8	282.9	616.5	236.1	349.8	334.5	563.1	504.2	388.3	4867.6
	1973	457.8	412.5	351.2	357.5	942.3	536.5	261.4	268.2	234.9	447.3	482.3	510.2	5262.1
	1974	903.4	217.6	212.1	288.7	199.7	304.6	186.5	322.1	458.8	762.1	270.6	339.1	4465.3
	1975	613.4	295.9	640.8	227.3	354.3	217.4	180.9	240.2	309.8	362.2	228.6	334.4	4005.1
	1976	482.4	424.3	356.5	320.2	805.2	203.5	180.6	377.9	506.2	291.5	539.9	307.4	4795.5

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 77 km/h, AND OCCURED FOR 1 HOURS.

CORAL HARBOUR A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 64° 12'N
LONGITUDE: 83° 22'W
ELEVATION: 59 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	18.5	20.4	18.7	18.5	19.9	19.1	18.4	18.3	20.4	20.9	23.4	18.1	19.5
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	418.2	520.5	447.2	406.3	489.4	359.5	304.0	297.5	397.9	454.0	792.9	402.4	5289.7

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	109.0	196.8	503.0	520.3	1011.9	289.4	260.7	406.4	653.0	621.7	1214.3	400.1	6186.5
	1968	470.6	1174.7	397.9	430.7	471.5	181.9	488.7	317.6	350.9	380.9	484.3	495.4	5645.1
	1969	467.5	476.1	612.3	222.2	1075.3	570.1	211.6	226.7	357.1	457.0	1527.3	144.7	6348.0
	1970	638.7	748.8	891.5	212.6	495.7	595.3	325.2	213.1	445.8	448.5	1000.5	453.1	6468.9

1971	755.2	355.9	144.5	583.2	296.7	321.7	205.2	323.4	442.4	382.1	387.6	313.9	4511.8
1972	592.9	786.2	217.6	360.4	156.0	182.2	311.6	187.9	241.6	238.0	232.0	118.1	3624.6
1973	219.3	351.1	402.0	544.6	356.1	401.8	471.4	229.3	435.7	716.5	961.7	353.6	5443.0
1974	139.7	599.0	669.2	492.9	275.4	319.2	116.1	303.5	188.3	319.5	454.7	107.3	3984.6
1975	295.3	307.7	229.2	121.9	218.9	242.2	301.5	443.8	391.6	631.7	668.6	876.5	4728.9
1976	493.9	368.3	404.4	573.9	536.2	491.3	347.9	323.2	472.4	343.8	997.4	772.6	6125.3

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 100 km/h, AND OCCURED FOR 4 HOURS.

CAPE DYER A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 66°35'N
LONGITUDE: 61°37'W
ELEVATION: 376 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	16.8	14.4	12.7	11.5	12.9	9.9	9.6	10.7	13.4	14.4	14.6	14.9	13.0
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	763.2	436.3	455.2	253.7	299.6	134.8	111.5	150.6	244.0	314.9	391.5	560.7	4116.0

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
1967	582.7	822.4	180.4	387.7	187.1	165.0	104.2	118.7	414.1	233.1	303.5	287.0	3785.9
1968	1671.2	294.4	412.6	347.8	326.6	175.0	165.7	240.3	209.0	282.6	632.0	760.6	5517.8
1969	382.9	154.6	121.8	149.3	94.1	32.7	72.1	25.8	194.7	383.4	165.8	248.0	2025.2
1970	616.8	611.6	494.2	204.4	180.8	275.2	190.0	115.9	226.1	403.3	372.2	663.7	4354.1
1971	890.2	443.7	164.3	77.6	281.1	40.3	47.5	198.9	447.5	295.5	368.4	312.3	3567.3
1972	728.1	471.7	546.1	205.7	530.7	282.1	101.0	143.3	193.9	254.6	115.3	1094.0	4666.4
1973	1014.3	244.0	98.7	221.9	177.7	127.2	55.6	183.1	210.6	153.1	228.6	503.7	3218.5
1974	633.8	459.1	813.3	121.4	157.5	43.1	77.3	153.0	141.3	456.8	674.2	202.6	3933.4
1975	586.0	654.0	782.1	171.4	785.4	54.5	70.5	140.5	155.0	224.2	514.9	587.1	4725.4
1976	526.1	370.4	938.4	649.9	275.3	152.9	230.8	186.3	247.8	462.6	540.0	960.6	5540.9

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 126 km/h, AND OCCURED FOR 1 HOURS.

FROBISHER BAY A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 63°45'N
LONGITUDE: 68°33'W
ELEVATION: 21 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	14.4	13.2	12.3	15.2	16.3	14.2	11.6	12.9	14.7	15.6	16.5	13.8	14.2
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	286.3	200.5	252.3	269.0	243.8	155.1	108.5	148.1	189.4	209.7	275.2	258.5	2596.4

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	365.6	129.8	113.4	198.8	188.8	113.5	84.9	90.6	296.9	187.5	409.4	166.7	2365.9
	1968	349.3	306.4	135.1	245.6	213.1	141.1	95.6	95.7	201.4	85.0	306.9	213.2	2390.4
	1969	109.0	261.2	209.7	181.9	220.0	52.8	84.5	87.7	119.0	133.5	206.6	317.0	1982.8
	1970	241.6	190.7	141.9	255.9	192.9	239.9	118.9	94.9	135.8	259.5	319.9	453.3	2645.2
	1971	263.6	121.2	107.1	122.1	225.6	62.9	39.0	65.5	158.6	210.2	124.7	100.2	1600.7
	1972	181.7	197.7	184.2	207.9	188.7	147.4	75.4	94.8	114.4	202.3	105.0	294.3	2003.8
	1973	407.2	89.0	206.9	115.9	92.0	82.4	55.2	73.9	65.1	125.5	168.6	177.3	1656.9
	1974	314.8	208.4	245.6	137.9	122.1	91.5	54.0	124.4	93.1	238.3	231.9	99.4	1961.4
	1975	167.2	131.6	521.3	564.8	479.2	279.5	165.1	290.9	400.2	328.8	461.8	349.8	4140.2
	1976	443.5	427.8	658.1	658.1	506.2	339.7	312.2	463.0	309.3	326.2	417.1	419.0	5278.9

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 82 km/h, AND OCCURED FOR 3 HOURS.

RESOLUTE A, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 74°43'N
LONGITUDE: 94°59'W
ELEVATION: 64 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	20.1	19.8	19.7	17.3	21.7	20.7	20.7	21.7	26.7	26.8	21.7	20.3	21.4
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	655.0	529.8	582.9	455.3	586.6	418.4	453.7	513.3	786.7	906.0	690.4	612.1	7182.3

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	590.9	245.5	584.5	269.9	1013.4	435.9	732.5	1103.3	841.4	1089.5	132.6	645.9	7685.4
	1968	367.3	336.5	583.5	536.9	531.2	482.8	531.4	437.0	1038.3	1176.1	384.2	979.9	7387.1
	1969	595.9	417.0	707.6	437.4	312.0	112.4	145.1	407.2	813.3	1074.7	1387.9	630.6	7041.3

1970	832.2	1108.8	555.7	186.6	348.8	333.0	179.2	251.6	825.7	649.7	1102.2	681.0	7034.1
1971	1492.0	604.4	824.6	1390.4	781.1	597.4	585.1	669.6	596.3	886.1	606.4	483.9	9516.2
1972	390.5	544.7	827.2	471.2	621.9	381.7	604.3	382.4	797.4	987.3	571.6	390.6	6870.9
1973	583.2	475.7	642.2	204.6	935.7	681.6	549.1	477.3	958.0	1402.9	420.2	538.9	7870.3
1974	408.5	345.4	245.1	360.4	533.2	572.1	482.7	494.3	1077.0	839.9	631.9	848.5	6838.9
1975	712.0	897.9	392.9	321.1	513.2	260.6	284.2	228.6	361.4	658.0	1043.0	422.6	6095.3
1976	577.5	519.7	465.5	394.3	275.1	326.5	443.5	681.1	556.9	313.9	614.8	494.9	5663.7

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 108 km/h, AND OCCURED FOR 1 HOURS.

CHURCHILL A, MAN. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 58°45'N
LONGITUDE: 94° 4'W
ELEVATION: 29 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	23.2	24.2	20.9	20.4	20.6	20.3	18.8	19.6	22.3	24.6	24.7	20.2	21.6
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	499.1	504.8	436.9	343.2	328.9	279.1	239.6	281.5	426.5	624.8	713.4	397.5	5076.2

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	412.9	536.5	821.2	502.9	518.8	545.1	450.9	357.6	733.6	617.0	1156.7	826.7	7479.9
	1968	498.9	797.3	834.7	465.6	359.2	256.4	199.4	220.9	245.3	297.3	372.0	426.1	4973.2
	1969	466.1	242.8	666.2	456.6	641.5	333.6	236.0	462.4	320.3	1028.6	1236.7	494.8	6585.5
	1970	606.7	991.0	422.5	243.7	263.6	363.0	323.3	407.3	545.3	891.8	621.7	118.0	5776.9
	1971	523.4	273.9	89.3	176.3	182.1	195.2	194.7	215.5	402.2	404.8	482.2	496.4	3846.0
	1972	510.7	548.5	280.4	398.6	287.0	310.2	195.8	250.4	598.0	697.1	375.9	303.8	4776.5
	1973	477.6	584.1	314.7	439.5	237.7	201.6	164.4	198.3	621.5	570.1	1186.5	255.2	5252.1
	1974	318.1	382.4	314.8	332.7	180.7	208.0	155.4	215.7	263.5	719.5	523.2	247.3	3862.3
	1975	691.6	581.2	366.9	160.7	254.1	138.4	189.9	222.8	276.2	448.9	416.7	388.5	4136.8
	1976	485.8	287.9	248.4	255.8	373.6	248.9	284.8	263.3	259.3	570.6	751.8	418.7	4448.7

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 95 km/h, AND OCCURED FOR 1 HOURS.

COPPERMINE, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 67°50'N
LONGITUDE: 115° 7'W
ELEVATION: 9 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	20.1	16.6	16.1	13.5	14.9	13.1	14.6	17.2	18.4	19.4	17.8	16.9	16.5
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	430.2	252.1	266.1	169.3	189.4	116.1	140.5	215.1	274.4	364.8	299.0	275.7	2992.7

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	219.9	226.8	518.5	169.4	229.5	155.8	122.7	169.3	248.7	215.3	232.0	328.2	2836.1
	1968	221.6	226.7	238.0	150.7	191.4	88.2	135.6	264.0	248.7	371.8	386.2	303.5	2826.3
	1969	267.6	134.3	215.4	169.5	219.9	77.2	137.5	203.7	186.3	329.2	385.1	189.5	2515.1
	1970	280.2	233.6	220.5	123.7	101.6	120.1	210.8	266.8	458.6	358.1	203.3	240.1	2817.3
	1971	868.4	136.6	280.0	234.4	166.1	59.2	159.9	206.3	285.0	488.1	228.2	264.8	3376.1
	1972	594.8	362.1	328.4	152.3	277.1	164.8	108.5	166.7	260.9	450.1	336.7	396.0	3598.2
	1973	466.5	372.7	133.1	96.0	214.3	141.4	111.2	254.0	161.7	226.3	295.7	264.0	2737.0
	1974	620.5	177.3	235.3	152.9	106.4	130.2	123.3	207.7	425.4	513.1	151.8	122.1	2966.0
	1975	417.3	353.2	209.0	260.1	210.1	92.5	170.2	189.8	301.1	373.5	474.2	267.0	3318.0
	1976	345.2	379.5	282.5	184.2	177.9	131.6	125.7	222.7	167.2	322.3	296.7	385.6	3021.2

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 87 km/h, AND OCCURED FOR 1 HOURS.

CONTWOYTO LAKE, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 65°29'N
LONGITUDE: 110°22'W
ELEVATION: 451 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	17.6	16.3	16.0	16.1	17.9	16.1	15.2	19.9	23.2	23.9	16.8	16.3	17.9
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	396.4	267.7	299.3	234.6	294.0	194.7	172.5	328.2	493.6	559.0	280.1	289.2	3809.4

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	110.8	150.7	579.8	247.0	404.8	328.1	102.6	303.0	541.9	363.3	257.6	529.1	3918.7
	1968	252.7	279.1	229.6	220.1	288.4	175.7	185.0	371.4	284.5	333.0	310.2	230.9	3160.6

1969	220.2	175.8	164.5	186.1	164.1	196.1	111.8	186.9	258.4	496.5	377.9	179.5	2717.7
1970	489.9	249.1	344.3	188.8	156.2	254.0	215.6	445.3	749.1	491.6	87.1	209.8	3880.8
1971	990.1	198.5	284.9	315.5	307.5	94.6	240.1	389.7	650.5	607.0	173.8	412.1	4664.1
1972	425.9	424.8	302.8	325.9	410.0	217.4	228.3	176.1	451.2	576.4	399.7	243.0	4181.5
1973	208.5	342.9	341.6	182.8	306.2	141.8	169.9	386.3	380.0	512.3	200.4	216.9	3389.6
1974	634.6	172.1	294.4	220.6	243.4	224.4	232.2	491.4	878.3	1208.1	177.3	253.1	5029.7
1975	334.2	392.0	210.0	211.1	460.5	130.2	137.1	342.1	505.1	538.9	546.3	258.0	4065.5
1976	297.1	378.4	240.8	248.1	198.5	184.7	102.2	190.0	237.2	463.1	270.5	362.3	3172.8

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 105 km/h, AND OCCURED FOR 1 HOURS.

CHESTERFIELD, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 63° 20'N
LONGITUDE: 90° 43'W
ELEVATION: 6 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	21.3	24.6	22.9	20.6	19.9	17.6	16.6	18.9	23.4	25.9	22.2	19.2	21.1
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	433.8	604.7	539.2	432.2	333.9	245.1	182.3	276.1	533.7	722.5	502.7	355.5	5161.7

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	317.6	681.1	1037.4	847.6	388.5	269.1	205.0	556.3	1148.7	790.4	594.9	549.4	7386.1
	1968	509.0	857.6	461.8	525.1	386.9	194.9	276.1	234.9	487.7	537.2	428.8	422.4	5322.6
	1969	366.7	325.8	510.6	308.4	478.1	221.0	126.1	135.5	486.1	1234.1	711.0	222.9	5126.2
	1970	504.9	737.4	765.0	158.8	235.4	541.0	212.5	254.1	518.7	977.6	548.0	119.0	5572.5
	1971	326.4	450.9	174.7	688.0	328.7	166.5	110.3	317.9	518.7	614.7	356.0	369.0	4421.9
	1972	485.2	837.4	303.5	527.3	309.4	216.8	143.3	131.2	360.3	557.4	351.5	202.3	4425.5
	1973	458.9	679.3	566.0	274.6	266.7	184.0	123.5	220.8	658.6	541.5	467.5	295.6	4737.1
	1974	273.8	338.1	454.0	315.3	143.9	192.1	170.8	257.4	336.9	738.3	434.5	225.9	3880.9
	1975	514.1	464.3	514.2	178.4	249.3	155.0	259.6	190.7	349.4	635.9	497.4	432.7	4440.9
	1976	581.0	865.9	604.2	498.7	551.9	310.6	196.1	462.3	471.4	597.6	637.0	727.9	6904.5

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 93 km/h, AND OCCURED FOR 2 HOURS.

SACHS HARBOUR, NWT. WIND SUMMARY
ANALYSIS PERIOD: JAN 1967, TO DEC 1976.

LATITUDE: 71°59'N
LONGITUDE: 125°17'W
ELEVATION: 84 m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN WIND SPEED (km/h)	18.2	16.6	18.3	19.3	20.0	18.7	19.8	21.6	21.8	22.7	19.8	18.7	19.6
TOTAL POTENTIAL WIND ENERGY (MJ/m²)	340.2	232.4	322.6	339.0	321.3	240.4	280.0	373.6	410.0	511.2	398.8	335.2	4104.9

RECORDED POTENTIAL WIND ENERGY (MJ/m²) (MJ x 0.28 = kWh)

YEAR:													
	1967	79.5	190.8	237.5	214.9	261.7	229.5	169.1	282.7	278.6	386.9	318.0	482.0	3131.2
	1968	307.7	485.0	319.0	265.6	373.7	215.2	243.3	367.8	472.8	975.8	660.7	294.8	4981.2
	1969	183.9	171.1	269.1	698.6	282.2	264.7	359.4	431.1	336.0	402.1	264.8	383.7	4046.7
	1970	195.7	100.0	643.4	438.7	279.8	281.1	312.8	253.5	611.0	439.5	312.5	241.3	4109.3
	1971	400.9	65.8	603.7	448.8	332.3	200.8	264.3	475.2	412.1	649.1	525.0	150.7	4628.5
	1972	251.2	334.6	205.5	431.1	311.6	281.3	230.1	263.4	162.6	443.2	205.0	221.9	3341.4
	1973	325.4	318.6	211.6	216.3	432.4	176.4	269.7	285.7	185.9	526.6	686.3	692.3	4327.2
	1974	849.6	274.9	164.2	248.0	258.9	225.1	340.3	530.6	739.1	331.4	191.9	203.7	4357.6
	1975	510.5	133.2	263.5	202.0	291.6	199.0	322.7	414.0	348.0	350.6	119.2	332.5	3536.7
	1976	297.8	269.9	308.6	225.8	388.9	331.3	288.5	432.1	553.9	606.6	604.5	349.7	4657.6

THE MAXIMUM OBSERVED WIND SPEED IN THE ANALYSIS PERIOD WAS 80 km/h, AND OCCURED FOR 2 HOURS.

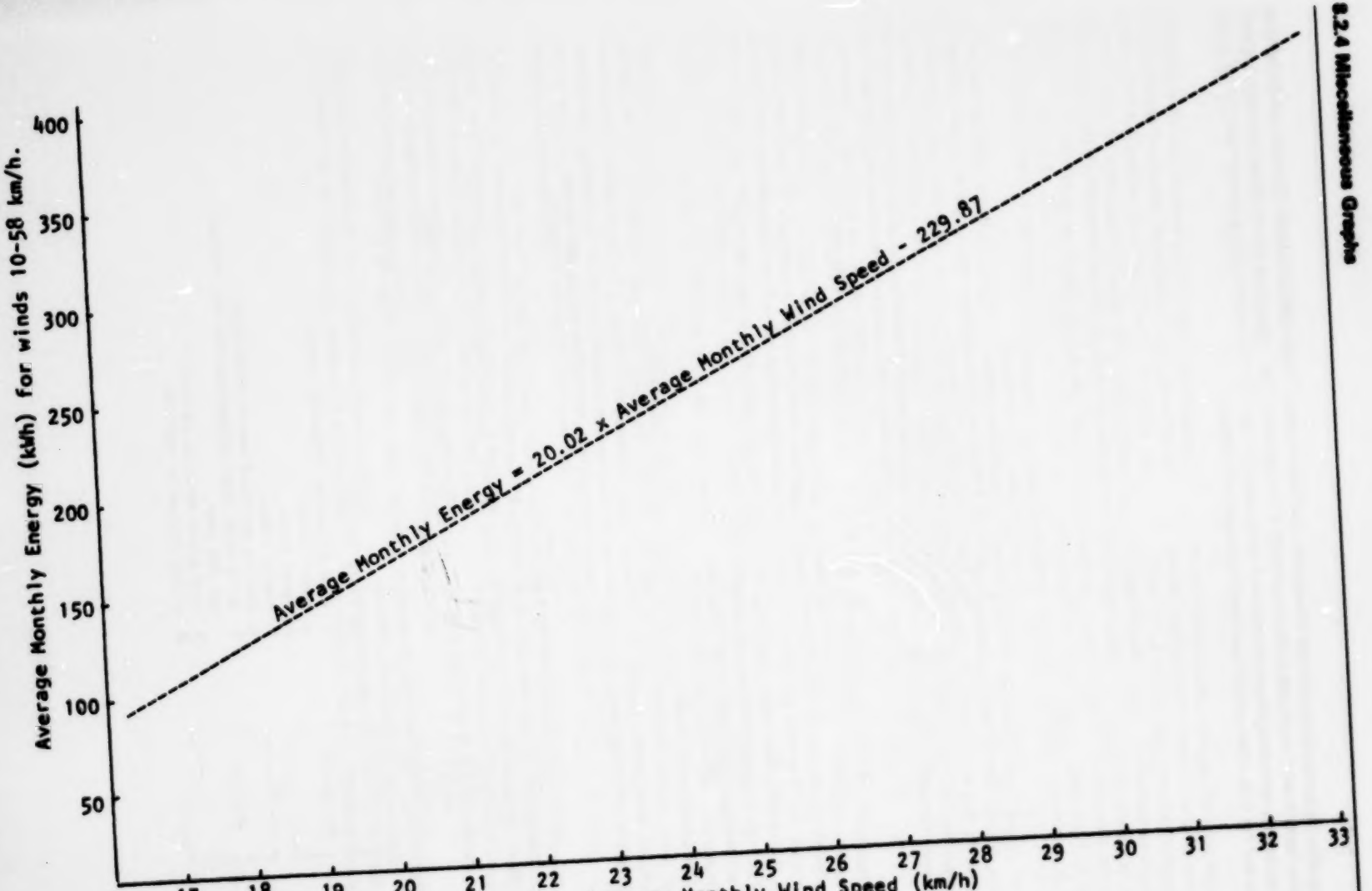
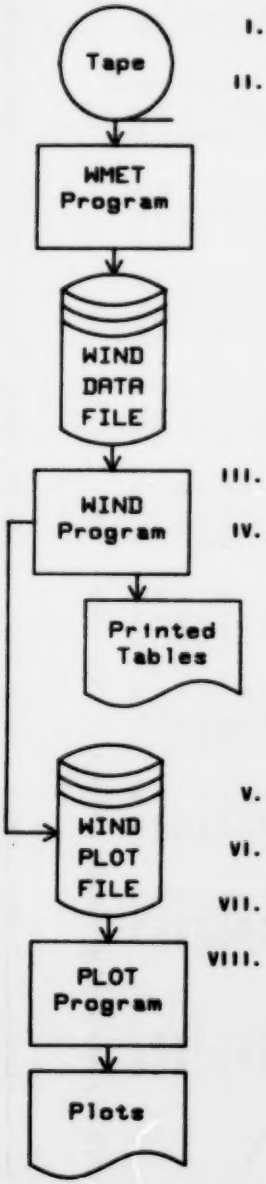


Figure 100. Average monthly energy as a function of average monthly wind speed — Betz factor not included (after Lamont).

Figure 101. Flow chart of computer program for site-specific graphs and tables. (The graphs of Chapter 5 and the wind-summary tables, Table 4, were produced on the Amdahl 470 V/8 computer at the University of Alberta. Raw data were supplied by the Atmospheric Environment Service on 9-track magnetic tape. The accompanying flow chart shows the programs used and the flow of data which produced the graphs and tables.)



I. Magnetic tape with hourly wind speed, direction, air temperature and air pressure data from 1967-1976.

II. The WMET program uses the data on the tape to calculate:

1. monthly mean air temperature,
2. monthly mean air pressure,
3. monthly mean wind speed,
4. monthly effective wind speed,
5. hourly average wind power,
6. monthly wind speed frequency,
7. monthly wind power frequency,
8. duration and frequency of continuous periods of wind speeds less than, and periods greater than 15,20,25,30 and 35 km/h,
9. actual wind energy recorded in each month of each year,
10. maximum wind speed and its occurrence,
11. monthly and annual mean speed, power and frequency of wind from 16 points of the compass.

III. The "Wind Data File" contains the results from program WMET.

IV. The WIND program uses the Wind Data File to calculate:

1. annual mean air temperature,
2. annual mean air pressure,
3. annual mean wind speed,
4. annual effective wind speed,
5. annual and monthly mean wind energy and power,
6. monthly averaged hourly wind power throughout the day,
7. monthly and annual mean wind energy from the 16 points of the compass.

V. "The Printed Tables" contain results from WMET and WIND.

VI. The "Wind Plot File" contains the results from WMET and WIND in a plottable form.

VII. The PLOT program plots the values from the Printed Tables.

VIII. The Plots include:

1. wind direction frequency roses,
2. power roses,
3. speed roses,
4. energy roses,
5. monthly averaged hourly wind power,
6. daily wind power throughout the day, throughout the year,
7. wind speed duration periods,
8. energy frequency profiles.

8.3 LOCAL WIND SYSTEMS IN THE NORTHWEST Territories (Notes by H. P. Wilson)

Complex local wind systems occur in many remote parts of the Northwest Territories. Reference to such winds has appeared in the literature since the days of the earliest explorers. Documentation as to frequency and extent of occurrence, however, is generally lacking. Evidence of such winds is seen in their effects on vegetation, sand dunes, and sand blasting. This section has a semi-technical discussion of some of these local wind systems.

Mountainous areas, with their complex terrain, are subject to anomalous winds. Winds tend to blow up and down valleys in response to the heating and cooling of the earth's surface. Certainly in some areas, such winds might be persistent enough and strong enough to make wind-energy applications feasible. There are many mountain locations, however, particularly in regions of the eastern Northwest Territories, where the valley winds are violent and of short duration. All valleys with glaciers at their head have a natural down-valley wind component. The normal up-valley component during daylight hours may block this for a period, but once darkness returns, there may be a violent down-valley wind for a few hours. These down-valley winds can move sizeable boulders.

The duration, strength, and extent of the chinooks in the valleys of the Mackenzie Mountains have not been documented, making it difficult to assess their potential for wind-energy applications. It may be that some valleys, such as the Nahanni, have sufficient wind in winter to make wind-energy applications feasible.

Chinooks, or foehn-type winds, also occur in the eastern parts of the Northwest Territories. The chinooks of the west generally consist of westerly winds; those of the east occur with southerly or southeasterly winds. The chinooks in the east are of relatively short duration, making them unsuitable for wind-energy applications (Bliss, 1977).

High land in a northwest-southeast oriented direction diverts a northerly flow to northwesterly resulting in convergence and increased winds against the height of land. For example, although the height of land between Coppermine and Fond du Lac is not a prominent terrain feature, it increases the winds in the area to its east.

Bays and islands affect the general wind regimes. For winds greater than 45 km/h, there is a cyclonic component of flow around a bay and an anti-cyclonic component around an island. For this reason, to an observer with his back to the wind, velocities are significantly greater to his right than to his left along a channel. For example, on the west side of Foxe Basin the strongest winds are from north-northwest, but on the east side they are southeasterly.

An area of persistent open water is favourable for cyclogenesis because of the diabatic effect. This is applicable to Foxe Basin and the area off Thule, showing up as persistent low pressure areas in those regions. Open water in October in the Mackenzie Bay area occasionally contributes to violent storms.

At some of the stations in the Northwest Territories, strong winds occur with two directions. Shingle Point, Resolute, and Alert are good examples. At Shingle Point, the persistent directions are west and east, parallel to the coast, but the strongest winds occur with a south or southwest flow. At that site there is a slope downward to the northwest and a pass through a main valley to the interior. Southerly winds occasionally have been strong enough to transport gravel 3 to 5 km out to sea. At Resolute the flow tends to be erratic and unstable when it is from the north. (Fraser, 1959; Burns, 1972). At Alert the strong wind directions are west-northwest and southwest. However, strong winds are infrequent. (Lee, 1972).

The runway at Horton River on the west side of Franklin Bay is located east of an escarpment. Strong west winds measured at 700 m elevation can totally reverse direction on the level of the runway. Instead of a downslope flow, there is an eddy to the lee of the escarpment.

The terrain at Winter Harbour is low to the north but relatively high to the northwest and northeast. Very strong northerly winds were recorded there by the 1820 Parry expedition and in 1958 when Bawden Drilling drilled the first oilwell.

Hall's Gate between Ellesmere and Devon Islands may be regarded as a narrow pass. A small patch of open water persists there in winter when the winds are stronger than during the rest of the year. The eastern side of Grinnel Peninsula is often windy during winter.

The channel between Ellesmere and Greenland widens out to the south. For this reason, the strong north winds through Robeson Channel tend to hug the west side of Smith Sound and produce the "north water" off the southeast corner of Ellesmere Island.

Along the east coast of Baffin island the strongest winds occur off Cape Dyer where the width across the channel is narrowest.

The strongest winds in Hudson Strait are west-northwest along the south side and across the channel. The winds tend to have cyclonic curvature.

In Hudson Bay, the circulation tends to be weakly cyclonic and the strongest winds tend to occur along the west coast, partly because of the presence of open leads parallel to the coastline.

In the vicinity of an icecap there is a glacier wind in summer, night and day. However, along the coast there is likely to be the land and sea breeze reversal. The Baird expedition reported that almost daily around 4 p.m. at the camp located midway between the coast and the foot of a glacier, the wind abruptly went from light to southwest 70 km/h for ten minutes or so. The shape and location of sand dunes indicated that this behaviour was not a rarity.

The pass northeast of Pangnirtung is interesting. When there is a northeast component of flow across the south half of Baffin Island, the winds could be very strong through the pass. Although such conditions occur frequently in winter, a good site for wind power may not be available because the flow is likely to be turbulent. The situation is similar to that of Kodiak in Alaska where northwest winds tend to produce "willie-waws".

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